MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. II. NO. 6.

THE OSTEOLOGY OF DIPLODOCUS MARSH.

With Special Reference to the Restoration of the Skeleton of Diplodocus Carnegiei Hatcher, Presented by Mr. Andrew Carnegie to the British Museum, May 12, 1905.

By W. J. Holland, LL.D.

In the first volume of the Memoirs of the Carnegie Museum, the late Mr. J. B. Hatcher gave an extended account of the Osteology of Diplodocus, based upon two specimens contained in the paleontological collections of the Carnegie Museum, numbered respectively 84 and 94 (Carnegie Museum Catalogue of Vertebrate Fossils), supplemented in part by information derived from the original descriptions of the late Professor O. C. Marsh, and the description of the pelvis and portions of the caudal vertebræ published by Professor Henry Fairfield Osborn in the Memoirs of the American Museum of Natural History, Vol. I., Part V. In the second volume of the Memoirs of the Carnegie Museum Mr. Hatcher published a brief paper, which he entitled "Additional Remarks on Diplodocus."[1] Since the publication of the foregoing papers the Carnegie Museum has secured a large quantity of additional material, consisting of two more or less imperfect skeletons, which are designated in

[1] Memoirs Carnegie Museum, Vol. II., p. 72.

Note.—The writer desires to express his sincere thanks to Professor Henry Fairfield Osborn and Dr. W. D. Matthew of the American Museum of Natural History, to Dr. Theodore Gill, Dr. George P. Merrill, Mr. C. W. Gilmore, and Mr. J. W. Gidley of the United States National Museum, and to Dr. Smith Woodward, Dr. C. W. Andrews, and Dr. G. A. Boulenger of the British Museum, for valuable suggestions and for allowing him to study the material contained in the great collections under their charge.

the Catalogue of Vertebrate Fossils of the Museum as Nos. 307 and 662. Moreover, a restoration of an entire skeleton has been prepared at the command and expense of Mr. Andrew Carnegie, at the suggestion of King Edward VII., of England, and this restoration was set up and installed by the writer in the Gallery of Reptiles at the British Museum and formally turned over to the Trustees of that institution by Mr. Andrew Carnegie on May 12, 1905. The restoration was made in the laboratories of the Carnegie Museum by Mr. Arthur S. Coggeshall, the efficient Chief Preparator in the laboratory, guided and directed in his work by Mr. J. B. Hatcher until the end of June, 1904, when his illness, succeeded by his lamented death, compelled the writer to assume supervision of the task, which had not been wholly completed. The more recently acquired material and the careful studies necessitated by the work of restoration have thrown new light upon the entire subject, and it is the purpose of the writer in the following pages to briefly point out the additions to our knowledge of the skeletal structure of the genus Diplodocus which have thus been secured. At the time of Mr. Hatcher's death the entire vertebral column from the axis to the extremity of the caudal series of vertebræ, so far as they are in our possession, had been placed in position, the ribs had been attached, and the fore and hind limbs erected. The atlas and the skull had not yet been restored or placed in position, nor had a disposition been made by Mr. Hatcher of the sternal plates, nor of the singular bone provisionally described by him as a clavicle.[2] The last professional interview between the writer and Mr. Hatcher took place in the Great Hall of the Exposition Society of Western Pennsylvania, where the restored skeleton was being assembled preparatory to shipment to London, and the time was spent in discussing with Mr. Hatcher the possible position which might be assigned to the so-called "sternal plates" and the supposed "clavicle." Mr. Hatcher confessed himself to be greatly puzzled, and the writer fully shared with him in the feeling of uncertainty, which prevailed in his mind, a feeling which has not been dissipated, and for excellent reasons, as will be made clear in the following pages. With the exception of the sternal plates and the supposed clavicle, there is no longer much doubt in the mind of the writer as to the function and relative position of all the bones which have thus far been recovered. The arrangement of the bones of the fore feet was made by Mr. Hatcher as the result of careful study, and the reproduction in the British Museum represents his views. The writer is, however, inclined to think that the manus in this reproduction is not represented in quite a natural position, and is disposed to the view that the feet should hold a position somewhat less digitigrade and more plantigrade than was given to them by his late associate.

[2] MEMOIRS CARNEGIE MUSEUM, Vol. I., p. 41, and Vol. II., p. 74.

THE SKULL.

Materials upon which our Knowledge of the Skull of Diplodocus is Based.

At the time when Mr. Hatcher published his first paper upon Diplodocus he made use of the words, "Unfortunately there is no skull of Diplodocus in our collections." He therefore repeated the figures and descriptions of Professor Marsh in order to make his account of the animal complete, so far as possible. One of the specimens secured for the Museum by Mr. W. H. Utterback, in Wyoming, in the year 1902 (Acc. $\frac{662}{22}$), yields the entire posterior portion of a skull in very perfect state of preservation. While the anterior portion of this skull and the lower jaws are missing, the specimen, which has been very carefully and skillfully freed from the matrix, throws a great deal of light upon the structure of the posterior portion of the skull. Both Mr. Hatcher and the writer were accorded by the authorities of the United States National Museum the fullest opportunity to examine and minutely study the two skulls upon which Professor Marsh based his description in his work upon the Dinosaurs of North America. (See Plates XXIII.–V.) These skulls were designated by Professor Marsh as specimen 1921 (U. S. N. M., No. 2672), and specimen 1922 (U. S. N. M., No. 2673). A cast of the latter, which is the more perfect specimen, was made with the consent of the officers of the United States National Museum. One half only of the external surface of this skull is thoroughly freed from the matrix. Using this half as the basis of our work, we restored the other half, using the portion of the skull belonging to the Carnegie Museum in modeling the occipital region. The skull employed in the restoration in the British Museum embodies in its outline the well-ascertained characteristics of these two skulls. Through the kindness of Professor Henry Fairfield Osborn we were enabled to secure for study a cast of the reproduction of the skull of a Diplodocus recently made by Mr. Hermann at the American Museum of Natural History. (See Plate XXVI.) This skull (A. M. N. H., No. 969) is based upon a specimen, somewhat fragmentary in character, obtained by the American Museum of Natural History, but it serves to illustrate some of the more important features of the structure under discussion. Mr. Hermann, so far as the external portions of the upper part of the skull are concerned, was unfortunately compelled to rely largely upon the figures and descriptions given by Professor Marsh, and in a few minor respects has not been quite successful in interpreting them. The restoration, though valuable, is defective, as was the original. In addition to the material mentioned above, which was at the command of the writer at the time the reproduction of the skull was prepared, there are in the possession of the American Museum of Natural History in New York the back portions of two other skulls (Nos. 545 and 694, Cat. Vert. Foss. A. M. N. H.). They both, according to Professor Osborn, represent individuals younger than the one used by him in making the restoration (No. 969), to which reference has been already made, and tend to throw light upon important points.

The Position of the Skull in Relation to the Vertebral Column.

Professor Marsh pointed out in his description of the skull the very important fact that the occipital condyle "is placed nearly at right angles to the long axis of

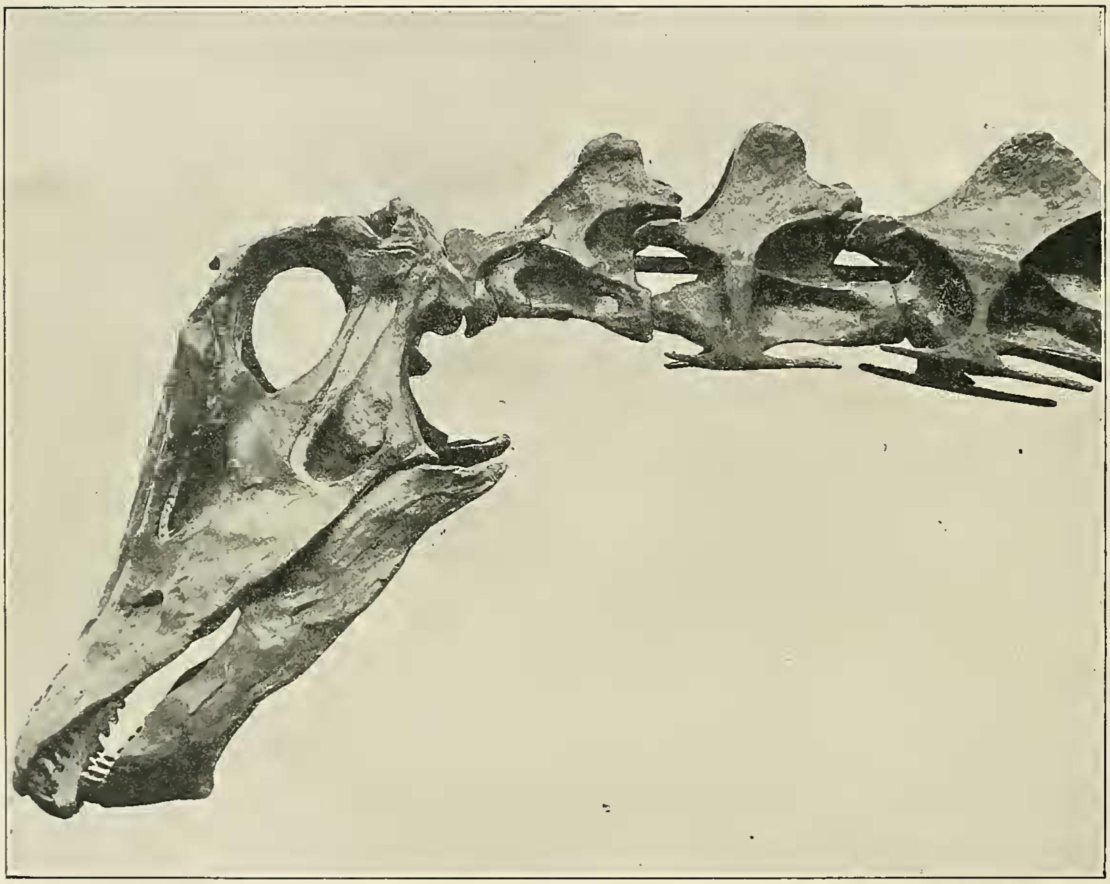

Fig. 1. Skull and anterior cervical vertebræ of *Diplodocus Carnegiei* Hatcher, as placed in the restoration at the British Museum (Natural History).

the skull." ("Dinosaurs of North America," p. 175.) In speaking of the brain he observes, *l. c.*, p. 178, that "It differed from the brain of the other members of the Sauropoda, and from that of all other known reptiles, in its position, which was not parallel with the longer axis of the skull, as is usually the case, but inclined to it, the front being much elevated, as in the ruminant mammals." When it became the duty of the writer to endeavor to assign the skull a position in the restoration in connection with the atlas and the axis, he was at once confronted by the fact that to place the skull with its longer axis in a line parallel with that of the cervical vertebræ was a mechanical and anatomical impossibility. The foregoing remarks of Professor Marsh had been overlooked by him at the moment, or they would have led him to a speedy solution of the difficulty. A careful study of the atlas, the axis, and the skull led him and his assistant, Mr. Coggeshall, after repeated failures to satisfactorily place the skull in the position usual among reptiles, to the final conclusion that the skull of Diplodocus in life was adjusted to the cervical series of vertebræ in such a manner that its longer axis formed an obtuse angle with the axis of the anterior cervical vertebræ. The correctness of this decision, which was the only one which could be reached, we subsequently found to be adumbrated and confirmed by the remarks of Professor Marsh, quoted above. Professor Marsh, though not called upon to articulate a skeleton of the animal, had with keen insight already detected the exceptional character of the skull with which he was dealing.

The figure on page 228 shows the skull of *Diplodocus* in the position assigned to it in the recent restoration of the skeleton. The attitude given the animal in the restoration is that which it might be imagined to have assumed when reaching for-

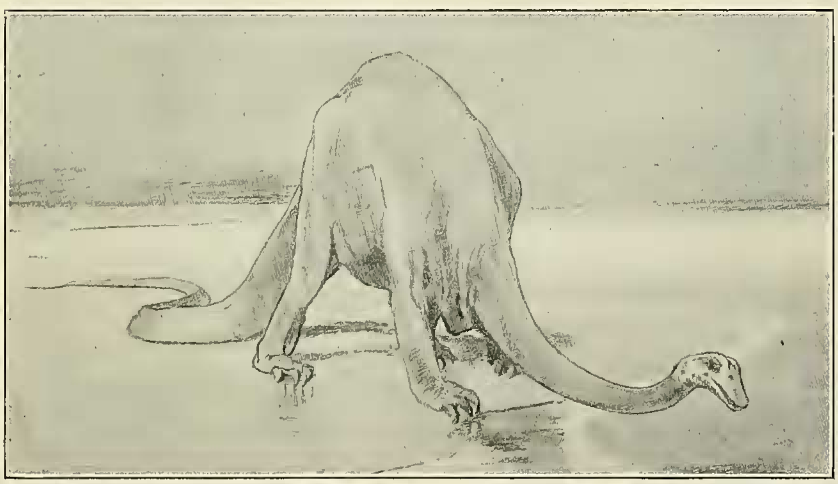

FIG. 2. Sketch by Miss Alice B. Woodward showing a supposable attitude of Diplodocus. (From the *Weekly Graphic*, London, May 13, 1905.)

ward with its long neck in quest of food. The motive in adopting this pose for the restoration was to bring the skull and the vertebræ of the neck within the range of easy vision on the part of observers. It is the opinion of the writer that the animal in life may often, and, in fact usually, when at rest, have held its head in a position analogous to that in which the head is held by the struthious birds, or, as an acquaintance well expressed it in conversation, in "a cameloid position." The attitude referred to is hinted at in a sketch made by Miss Alice B. Woodward, the accomplished daughter of Dr. Henry Woodward, F.R.S. This sketch was published by the London *Weekly Graphic* in its issue of May 13, 1905, and is herewith reproduced by permission of the editors of that publication.

Further anatomical confirmation of the correctness of the position of the skull given in the restoration is afforded by the study of the inferior surfaces of the atlas and the axis when they are brought into apposition and articulated. It will then be observed that their under sides form a gently arching surface. To attempt to bring the atlas and the axis into a position which would enable the longer axis of the skull to be placed in a direct line with the cervical vertebræ and to place these vertebræ in a line with their inferior faces set absolutely horizontally involves the dislocation of the neck.

The Bones of the Skull.

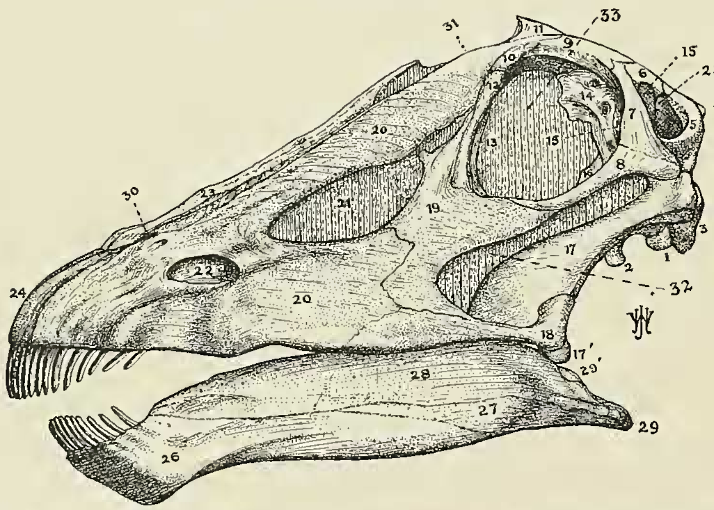

Fig. 3.—Side view of the skull of Diplodocus. 1, Occipital condyle; 2, basioccipital process; 3, end of left paroccipital process; 4, tip of posterior process of supraoccipital; 5, squamosal; 6, parietal; 7, postfrontal; 8, postorbital; 9, frontal; 10, prefrontal; 11, nasal; 12, supraorbital; 13, lachrymal; 14, orbitosphenoid; 15, alisphenoid; 16, presphenoid; 17, quadrate; 17′, hook-like lower end of quadrate; 18, quadratojugal; 19, jugal; 20, maxillary; 21, preorbital vacuity; 22, mesial foramen; 23, posterior processes of premaxillaries (according to Marsh); 24, premaxillaries; 25, supratemporal fossa; 26, dentary; 27, angular; 28, surangular; 29, articular; 29′, process of articular overlapping surangular; 30, foramen at posterior extremity of premaxillaries; 31, nasal opening (according to Marsh); 32, infratemporal vacuity; 33, orbital vacuity. (Figure one tenth natural size.)

The Basioccipital.—The basioccipital is terminated posteriorly by the occipital condyle, which, as has been pointed out by Professor Marsh, is "hemispherical, slightly subtrilobate in outline." The condyle is missing in Marsh's specimen No. 1922 (U. S. N. M., No. 2673) and he evidently based his description on specimen No. 1921 (U. S. N. M., No. 2672). The lower side of the bone in advance of the condyle is deeply concave longitudinally and convex transversely, throwing forward and downward a broad hypapophysis, which is divided into two portions, or basioccipital processes, at its anterior extremity. These processes point downward and backward. (See Figs. 3–5.) The body of the bone articulates by rough sutural surfaces with the basisphenoid, and the exoccipitals.

The Exoccipitals (Figs. 4–6, and 10).—The exoccipitals are broadly and strongly developed. Their inner margins, which are concave below, form the sides and the top of the foramen magnum in such a way as to show no trace of a suture in all specimens which the writer has examined. They send outward strong paroccipital processes, which are expanded above near their origin and again at their extremities. A sinus is thus developed upon the upper margin of the processes, and this forms the lower margin of the posttemporal fossa located between the paroccipitals and the squamosals, which by Professor Marsh was styled the "posterior fossa." The paroccipital processes articulate on the anterior surface of their outer

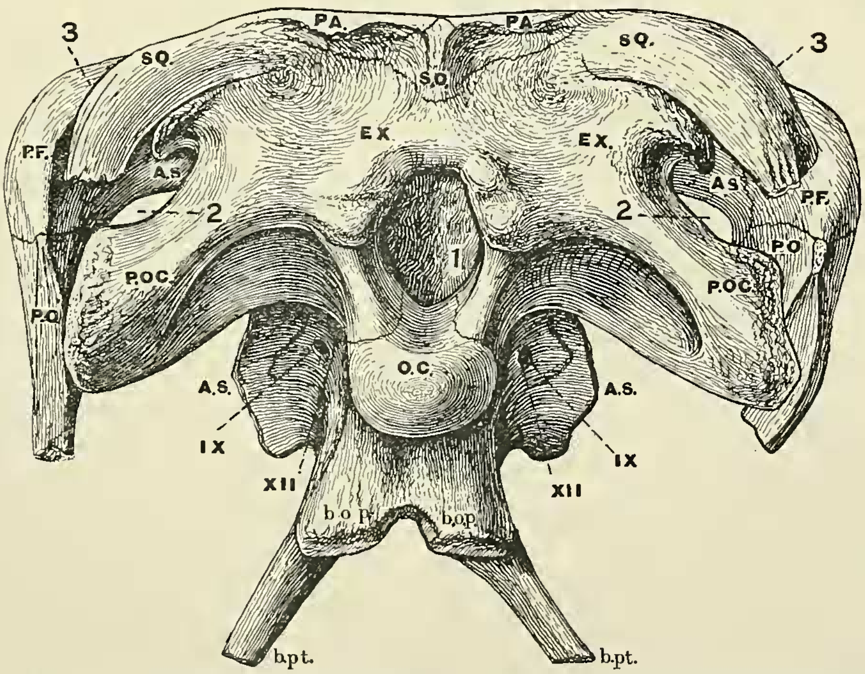

FIG. 4. Posterior view of back of skull of Diplodocus (No. $\frac{662}{22}$ Car. Mus. Cat. Vert. Fossils, one half natural size). *O.C.*, occipital condyle; *EX.*, exoccipitals; *S.O*, supraoccipital; *PA.*, parietals; *SQ.*, squamosals; *P.F.*, postfrontals; *P.O.*, postorbitals; *AS.*, alisphenoids; *P.OC.*, paroccipital processes of exoccipitals; *b.o.p.*, basioccipital processes; *b.pt.*, basipterygoid processes; 1, foramen magnum; 2, posttemporal fossæ; 3, supratemporal fossæ; *IX.*, glossopharyngeal foramina; *XII.*, condyloid foramina.

extremities with the quadrate bones. Their ends project slightly beyond the quadrates, and the posterior and marginal surfaces reveal provision for strong muscular attachments. They articulate below with the basioccipital and above this on either side by a wing-like process with the alisphenoid, the lower portion of the wing of which meets and overlaps the wing of the exoccipital. On either side of the supraoccipital they articulate with the parietals, and beyond these touch the squamosals along the proximal portions of the inferior margins of the latter bones. In front on either side they articulate with the alisphenoids.

The Supraoccipital (Figs. 3, 4, and 6). — The supraoccipital is a comparatively small bone, rudely defined as quadrilateral in outline viewed from behind, which is wedged in between the exoccipitals and the parietals. Its posterior surface is produced as a strong process at the middle of the occipital crest for the attachment of the nuchal ligament. Its upper anterior portion in specimen $\frac{662}{22}$ (Carnegie Museum Catalogue) appears to advance for a short distance on the median line between the parietals, and is more strongly advanced in specimen No. 694 (Cat. Am. Mus. Nat. Hist.). (See Plate XXVII., Fig. 2.) On either side of this point in the specimens which the writer has examined it appears to be wedged in underneath the parietals, articulating with them by irregular rugose surfaces.

The Parietals (Figs. 3–6). — The parietals are small bones placed one on each side of the occipital crest, their outer surfaces constituting the lateral portions of this crest. They articulate posteriorly with the supraoccipital near the median line of the skull and beyond this on either side with the exoccipitals. At their outer extremities they articulate with the squamosals, the upper edge of the alisphenoids, and the postfrontals. (See Fig. 5.) In front they articulate with the frontals. Concerning their relation to the pineal foramen the writer will have some observations to make elsewhere. (See p. 243.)

The Squamosals (Figs. 3–6 and 8–9.) — The squamosals are hook-shaped bones curving outwardly and downwardly, forming with the upper antero-external portions of the exoccipitals the posterior upper wall of the supratemporal fossa, which is relatively small, and, as Professor Marsh has described it, "oval in outline, and directed upward and outward." The squamosals articulate on the inner portions of their inferior margins with the paroccipital processes of the exoccipitals. The outer portion of their inferior margins is free for about half the length of the bone forming the upper margin of the posttemporal fossa which Professor Marsh[3] in the case of the skull of his so-called *Atlantosaurus* denominates "the posterior fossa," and which at its upper end is bifid, as in *Atlantosaurus*, owing to the projection into it of an

[3] Dinosaurs of North America, Pl. XV., Fig. 1.

upper enlargement of the paroccipital process which assumes the form of a smaller lateral blunt process directed outward and downward. The squamosals are thin at their lower curving ends, where they articulate with the inner surface of the quadrates, which at their upper end are wedged in between the paroccipitals and the postorbitals.

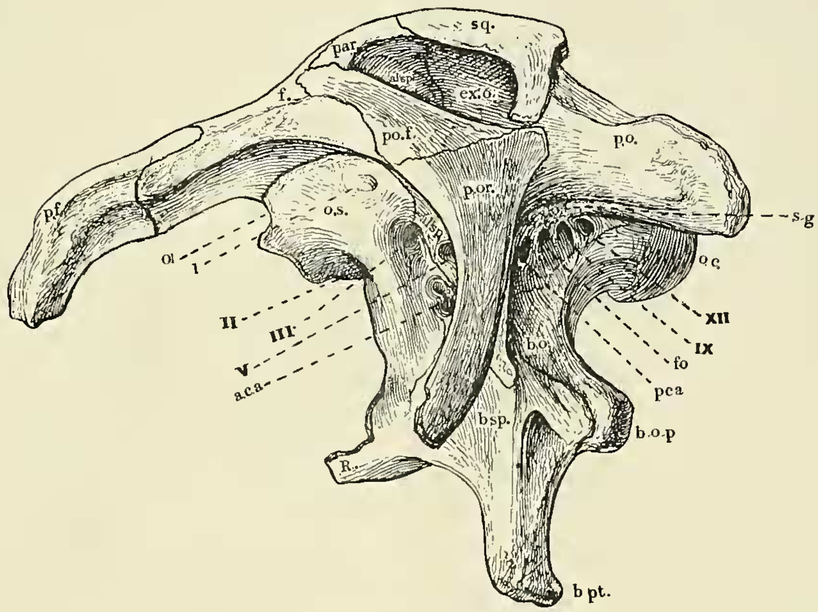

FIG. 5. Lateral view of the posterior portion of the skull of Diplodocus ($\frac{662}{22}$, Car. Mus. Cat. Vert. Fossils, one half natural size). *o.c.*, occipital condyle; *ex.o.*, exoccipital; *p.o.*, paroccipital process of exoccipital; *sq.*, squamosal; *par.*, parietal; *po.f.*, postfrontal; *f.* frontal; *p.f.*, prefrontal; *p.or.*, postorbital; *o.s.*, orbitosphenoid; *alsp.*, alisphenoid; *b o.*, basioccipital; *b.sp.*, basisphenoid; *b.o.p.*, basioccipital process; *b.pt.*, basipterygoid process; *R.*, presphenoid or rostral part of basisphenoid; *Ol.*, exit of olfactory nerves; *II.*, optic foramina; *III.*, oculomotor foramen; *V.*, trigeminal foramen; *IX.*, glossopharyngeal foramen; *XII.*, hypoglossal foramen; *a.c.a.*, foramen for anterior carotid artery; *p.c.a.*, foramen for posterior carotid artery; *fo.*, fenestra ovalis; *s.g.*, stapedial groove; 1, small foramen, possibly for vein.

The Frontals (Figs. 3, 5, 6, 8, and 10). — The frontals are paired, and united on the median line of the skull by a strongly toothed suture, extending in the specimen No. $\frac{662}{22}$ (Carnegie Museum Catalogue), from the point of union with the nasals to the parietals. The frontals over the orbital cavity are thick and heavy, measuring fully 1.5 cm. in thickness. They overlie the parietals posteriorly, and the nasals anteriorly, being bevelled in opposite directions on the lower side of the posterior and anterior margins for commissure with these bones. Each bone, viewed from above, sends out a short narrow anterior process at the point where they unite on the line of the median suture (Fig. 6, 4), and, another very long and broad process projecting forward, outward, and at its extremity downward (Fig 6, 5). This process is concavely bevelled below in front to receive the posterior margins of the nasals (Fig. 8, L. F. and R. F.) and grooved on its upper and outer side to receive the prefrontals (Fig. 6, P. F.). The orbital margin is horizontally concave (Fig. 6) and perpendicularly convex (Fig. 5). The posterior portions of the lateral margins of the frontals sweep downward to form the upper portion of the posterior wall of the orbital cavity, articulating with the alisphenoid, the postfrontals and the postorbitals. (See Fig. 8.) Along the posterior upper margin the frontals overlap the parietals, and articulate with the postorbitals on the upper margin of the process which the postorbitals send inwardly at the back of the orbital cavity. (See Fig. 8.)

The Postfrontals (Figs. 3–6, 8, and 9).— The postfrontals are small bones which overlap the frontals and the postorbitals, forming the upper portion of the anterior margin or wall of the supratemporal fossa and the upper posterior margin of the orbital arch. They articulate with the frontals and the postorbitals and posteriorly with the alisphenoid on the anterior wall of the supratemporal fossa. In the specimens studied by Professor Marsh he evidently regarded the postorbital bones as forming part of the postfrontals, and united the bones under the latter name. In his specimen (U. S. N. M., No. 2673) the distinctness of the postfrontals from the postorbitals is shown, and is conspicuously revealed in the specimen in the Carnegie Museum (No. $\frac{662}{22}$).

The Postorbitals (Figs. 3–6, 8, and 9).—The postorbitals assist in forming the posterior margin and a portion of the posterior and inferior inner walls of the orbital cavity. One portion of the bone extends as a somewhat sharp triangular process inwardly, being wedged between the posterior margin of the frontal bone and the upper portion of the wing of the alisphenoid which clasps it and supports it underneath. (See Fig. 8.) Above, this process is in part covered by the postfrontal where the latter bone unites with the external surface of the alisphenoid to form the anterior wall of the supratemporal vacuity. Externally where the postorbital articulates with the postfrontal the postorbital sends a process backward which articulates with the quadrate at the outer margin of the supratemporal fossa. The anterior part of the bone consists of a narrow process, triangular in section, running forward to a point where it articulates by an oblique suture with the upper posterior process of the jugal. The reëntering upper and lower surfaces of this process form respectively portions of the under surface of the posterior part of the orbital cavity and the upper surface of the posterior part of the infratemporal vacuity.

The Supraorbitals (Figs. 3 and 7).— The supraorbitals are long somewhat narrow bones forming very largely the anterior outer margin of the orbital cavity. They articulate above with the prefrontals and touch the uppermost posterior prolongation of the maxillary which borders the nasal opening; below they articulate with the superior process of the jugal, and along their posterior margin with the

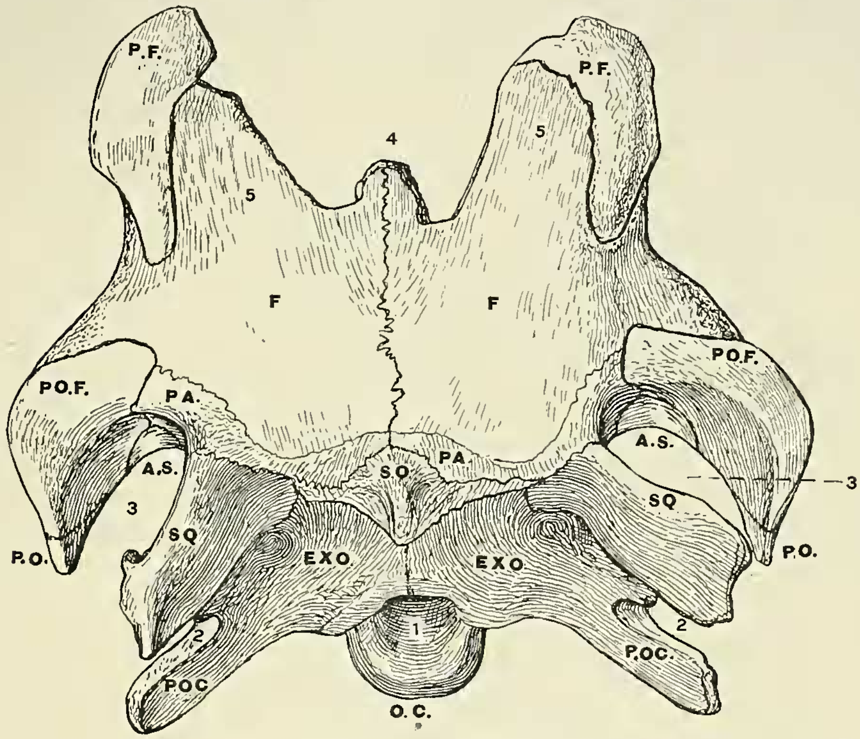

FIG. 6. Superior view of posterior portion of skull of Diplodocus (No. $\frac{662}{22}$, Car. Mus. Cat. Vert. Fossils, one half natural size). *O.C.*, occipital condyle; *EXO.*, exoccipitals; *P.OC.*, paroccipital processes of exoccipitals; *SQ.*, squamosals; *S.O.*, supraoccipital; *PA.*, parietals; *F.*, frontals; *PF.*, prefrontals; *PO.F.*, postfrontals; *P.O.*, postorbitals; *A.S.*, alisphenoids; 1, foramen magnum; 2, posttemporal fossæ; 3, supratemporal fossæ; 4, median anterior processes of the frontals; 5, lateral anterior processes of frontals.

FIG. 7. Supraorbital. Sketch of the outline of the bone as shown in Marsh's type specimen (U. S. N. M., No. 2673). The upper end is broken off in this specimen. (One half natural size.)

lachrymals. They might on account of their location be well styled preorbitals. In the specimen (U. S. N. M., No 545), the bone is shown dislodged from its place and bent back across the matrix which fills the upper part of the orbital cavity. In the specimen (U. S. N. M., No. 969), the bone is represented by some fragments (see Plate XXVI.), and in the specimen (U. S. N. M., No. 2672), it is shown just behind the antorbital vacuity. (See Plate XXIII.)

The Lachrymals (Fig. 3).—The lachrymals are thin plates of bone articulating along the lower posterior margin of the supraorbitals and forming a portion of the lower anterior wall of the orbital cavity. The bone is found *in situ* in the type specimen of Professor Marsh (U. S. N. M., No. 2673). (See Plate XXIII.) It does not appear to exist in the specimen in New York (U. S. N. M., No. 969).

The Basisphenoid (Figs. 5, 8, and 10).—The basisphenoid articulates posteriorly with the basioccipital and the exoccipitals and laterally with the alisphenoids and orbitosphenoids. The presphenoid or rostral portion is thin, occupying a vertical plane and forming a portion of the inner wall of the orbital cavity. The basisphenoid on either side sends downward and forward a remarkable long basipterygoid process and above these on either side sends out a flat lateral process which fuses with the lower wing-like processes of the exoccipitals and the alisphenoids at their point of conjugation.

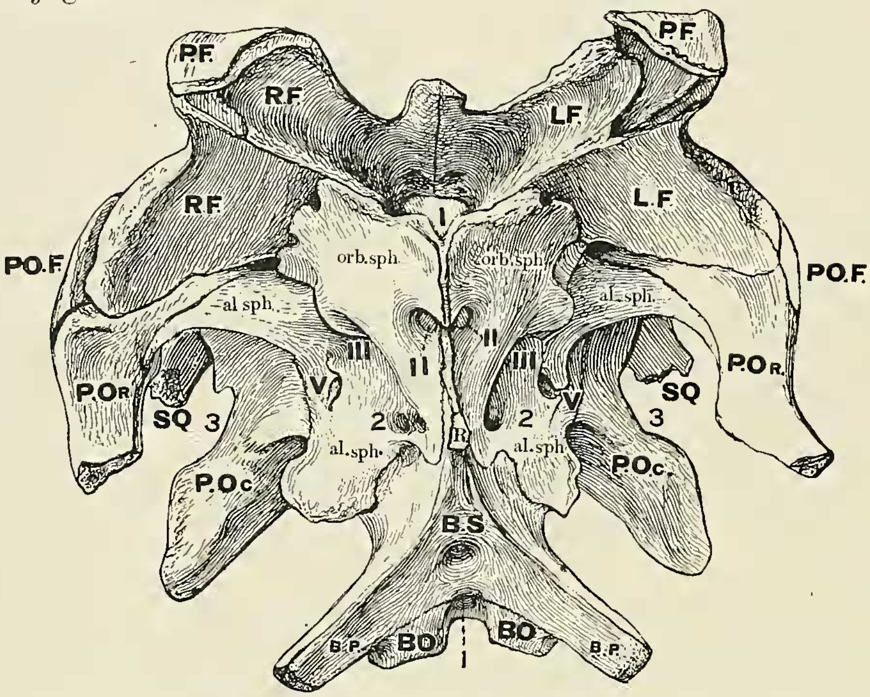

FIG. 8. Anterior view of posterior part of skull of Diplodocus (No. $\frac{662}{22}$, Car. Mus. Cat. Vert. Fossils, one half natural size). *P.F.*, prefrontals; *R.F.*, right frontal; *L.F.*, left frontal; *PO.F.*, postfrontals; *P.OR.*, postorbitals; *SQ.*, squamosals; *P.OC.*, paroccipital processes of exoccipitals; *BS.*, basisphenoid; *BO.*, basioccipital processes; *BP.*, basipterygoid processes; *R.*, rostral portion of basisphenoid; *orb.sph.*, orbitosphenoids; *al.sph.*, alisphenoids; *I.*, olfactory lobes; *II.*, optic foramina; *III.*, oculomotor foramina; *V.*, trigeminal foramina; 1, eustachian foramen; 2, foramina for anterior carotid arteries; 3, posttemporal fossæ.

The Alisphenoids (Figs. 3–6, 8, and 10). — The alisphenoids articulate dorsally with the frontals, postfrontals, postorbitals, parietals and exoccipitals; posterolaterally with the expanded wing of the exoccipitals where notches are formed on the line of conjugation for the exit of nerves, and anteriorly with the orbitosphenoids, at the line of union with which notches are likewise formed for the exit of nerves.

The Orbitosphenoids (Figs. 3, 5, 8, and 10). — The orbitosphenoids are paired meeting on the median line above the rostral prolongation of the basisphenoid. They articulate dorsally with the frontals and nasals, laterally with the alisphenoids, below with the basisphenoid. On the line of conjugation with each other notches are formed for the exit of nerves.

The Quadrate (Figs. 3 and 9 and Plate XXIII.). — The quadrate is a long bone articulating by its proximal extremity with the ends of the paroccipital processes of the exoccipitals, the squamosal, and the postorbital, uniting with these bones to form the outer margin of the supratemporal fossa. At its distal extremity it articulates for about five centimeters with the quadratojugal, under the posterior end of which it sends out a hook-like process for support. The quadrate at its lower extremity from about the middle broadens inwardly as a thin plate of bone, sending a process forward and downward to overlap the posterior ends of the pterygoid. This thin bony plate in part forms the inner lower wall of the infratemporal fossa.

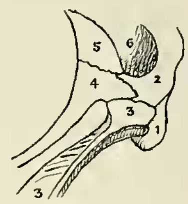

FIG. 9. Diagram showing the relation of the bones at the outer margin of the supratemporal fossa. 1, paroccipital process of exoccipitals ; 2, squamosal ; 3, quadrate ; 4, postorbital ; 5, postfrontal; 6, supratemporal fossa.

The Quadratojugal (Fig. 3 and Plates XXIII. and XXVI.).— The quadratojugal articulates in the manner already described with the quadrate by a flattened enlarged head, underlaid and hung in the hook-like extremity of the quadrate. The bone narrows below the infratemporal fossa into a comparatively narrow bar, and then widens to the line of articulation with the jugal and the maxillary. Just below this union along the outer margin of the upper jaw the bone expands and flares out horizontally. The manner of its articulation at both ends is best revealed by specimen No. 2673, U. S. N. M. (See Plate XXIII.) The specimen (A. M. N. H., No. 969) (see Plate XXVI.) has been restored in such a manner as to fail to show the true manner of articulation.

The Jugal (Fig. 3 and Plates XXIII. and XXVI.). — The jugal is a thin, very irregularly shaped bony plate which sends backward a long narrow process to articulate with the anterior process of the postorbital, with which process it unites to form the lower margin of the orbital cavity. Below it sends back another long narrow process to articulate with the quadratojugal. Between these two processes is a broad sinus forming the anterior margin of the infratemporal vacuity. Above, the jugal bone sends up a process which articulates with the preorbital at its lower end. This superior process further sends forth a small lateral process directed upward and forward, and projecting deeply into the posterior portion of the antorbital vacuity. The lower portion of the anterior margin of the jugal articulates by an irregularly curved line with the posterior border of the maxillary.

The Nasals (Fig. 3 and Plates XXIII. and XXIV.). — The nasal bones are paired bones somewhat semilunar in shape when seen from above. They are quite thin on their anterior margins, thick behind and are convexly bevelled posteriorly in order to articulate with the anterior margin of the frontal bone. They articulate also with the prefrontal bones along the anterior portion of their hind margins, the prefrontals being concavely bevelled at their extremities like the frontals, in order to receive them.

The Maxillary (Fig. 3 and Plates XXIII., XXIV. and XXVI.).—The maxillary is very largely developed and consists dorsally of a thin bony plate of irregular triangular outline forming the greater portion of the superior surface of the external walls of the facial region of the skull. On its ventral aspect it sends inwardly from its outer margin a broad lower plate, throwing out two long backward processes the innermost of which articulates, according to Professor Marsh, with the vomer, and the outermost of which articulates with the palatine, according to the same author.

The Premaxillaries (Fig. 3 and Plates XXIII., XXIV. and XXVI.). — The premaxillaries are paired subtriangular bones, occupying the triangular space in front of the skull between the maxillaries. They consist of an upper and lower bony plate. In all specimens examined by the writer the number of teeth in each premaxillary is four.

Premaxillary Processes (Fig. 3 and Plates XXIII., XXIV. and XXVI.).—Ranging backward from the premaxillaries, located between the maxillaries, are the two long slender bones, which Professor Marsh interprets as backward prolongations or processes of the premaxillaries, but which may be regarded as lateral ethmoids. These bones on the median line of the skull unite to form a raised ridge, which is higher in front than behind. At the anterior point of commissure the bones widen outwardly somewhat and terminate in blunt, outwardly obliquely truncated ends, which are raised above the level of the premaxillaries and maxillaries. There are at this point two moderately large foramina, one on either side, the purpose of which is yet to be determined, but which correspond more nearly in location to the nares as ordinarily found in the reptilia than any other openings in the skull.

Pterygoids, Palatine, and Vomer. — Professor Marsh's description of these bones was evidently based upon studies made by him after having taken the specimen (U. S. N. M., No. 2673) apart, so as to permit of a satisfactory examination of the roof of the mouth. At the time when the specimen was returned to the United States National Museum it was in separate pieces, and these have been reassembled so that it is now impossible to make a minute examination of the bones referred to, more particularly the palatine and the vomer. There is no reason to question the essential correctness of the brief descriptions and the figures given by Professor Marsh.

The Dentary (Fig. 3 and Plates XXIII. and XXVI.). — In the figure of the lower jaw given by Professor Marsh, "Dinosaurs of North America," Plate XXV., Fig. 1, he apparently represented the dentary as forming the superior border of the mandible for a considerable distance behind the last tooth of the lower series, and as forming the lower border of the mandible as far as a point a little back of the middle of the jaw. A critical examination of the skull (U. S. N. M., No. 2672) made by the writer in conference with Messrs. J. W. Gidley and C. W. Gilmore seems to show that the surangular extends forward almost to the point where the last teeth occur, and overlaps the dentary, while the dentary extends much further backward than is shown in Professor Marsh's figure. A comparison of Fig. 3 with Professor Marsh's figure reveals the difference in the interpretation given by the writer from that given by Professor Marsh in the drawing published by him.

The Surangular (Fig. 3 and Plates XXIII. and XXVI.).—The surangular externally overlaps the dentary from a point just back of the last tooth and forms the upper border of the jaw, extending externally almost to its posterior extremity. For about half of its posterior portion it articulates with the angular which is interposed between the posterior upper margin of the dentary and the lower posterior margin of the surangular. Internally the inner lamina of the surangular, beginning about three centimeters back of the symphysis, overlaps the dentary. Along its posterior inner surface it was apparently overlapped by the splenial which in the type specimen (U. S. N. M., No. 2672) seems to have been in great part broken away and lost, only some fragments of the lower posterior border remaining visible, wedged in between the surangular and the anterior internal prolongation of the articular.

The Angular (Fig. 3 and Plates XXIII. and XXVI.).—In the type specimen the angular is externally shown to be wedged in between the posterior margins of the dentary and the surangular, and extends backward to the extremity of the jaw. Internally it is shown to have had a heavy thickened middle portion lying back of the dentary and overlapped by an anterior prolongation of the articular.

The Articular (Fig. 3 and Plate XXIII.).—The articular forms the articulating surfaces of the jaw, overlapping the surangular at the posterior extremity by a well developed lateral process, and internally sending forth a long narrow prolongation.

The Coronoid.—In the specimen No. 2672 (U. S. N. M.) the coronoid like the splenial appears to be missing, the specimen being in this region somewhat defective.

The Teeth (Fig. 3 and Plates XXIII., XXIV., and XXVI.).—Professor Marsh pointed out the fact that the dentition of Diplodocus is weak. In all specimens of Diplodocus which have been examined there are four teeth in each premaxillary, as has already been pointed out. The number of teeth in the maxillaries and the dentary varies. In the specimen on which Professor Marsh founded his description there were nine teeth in the maxillaries and ten in the dentaries. In the specimen preserved in the American Museum of Natural History the number of teeth in the dentaries corresponds with the number given by Professor Marsh, but in the right maxillary in this specimen there are ten teeth while in the left maxillary there are eleven. The successional teeth are numerous, and nature provided the animal with the means of replacing a tooth almost as soon as it was lost. The arrangement of the teeth is rake-like, without distinct provision either for cutting or grinding, and suggests to the mind that they were employed for gathering soft succulent vegetation, which may have grown in masses upon the rocks of the shore. The feeding habits of the creature are, of course, unknown, but such teeth are apparently better adapted to raking and tearing off soft masses of clinging algæ than any forms of vegetable food which now exist in the waters of the world.

Openings in the Skull.

Larger Foramina. — The larger openings in the skull are the foramen magnum, the posttemporal fossæ, the supratemporal fossæ, the infratemporal vacuities, the orbital cavities, the narial opening, the preorbital vacuities, the large openings in the maxillaries, which I have designated as the mesial foramina of the maxillaries, and the foramina at the point of union of the premaxillaries and the long bones regarded by Professor Marsh as posterior processes of the premaxillaries.

The Foramen Magnum (Figs. 4 and 6 and Plates XXV., XXVI., and XXVII.). — The foramen magnum is bounded below by the basioccipital, and on either side and above by the exoccipitals. In specimen $\frac{662}{22}$, where there has been no crushing whatever in this region, the foramen is shown to be approximately ovoid in outline, with the longer axis perpendicular, the upper end decidedly narrower than the lower end of the opening. (See Fig. 4.)

The Posttemporal Fossæ (Figs. 4, 6, 8, and 10, and Plates XXV. and XXVI). — These are paired, one on either side of the exoccipitals. Each opening is bounded on its lower margin by the excavated margin of the paroccipital process of the exoccipital bones, and is bounded above by the lower margin of the squamosal. The upper end of the opening, when viewed from behind, is bifid, because of the intrusion into it of a short, blunt process which is sent forth downwardly and outwardly from the upper margin of the exoccipitals where they articulate with the squamosal. The lower extremity of the opening is closed by the proximal end of the quadrate.

The Supratemporal Fossæ (Figs. 3–6 and 10 and Plates XXIII.–XXVIII.). — The supratemporal fossa is oval in form, and is directed upward and outward. Its walls are formed behind, at the extreme upper inner margin, by the outer surface of the parietals for a short distance. The remainder of the posterior wall is formed by the forward surfaces of the exoccipitals and the squamosals. The anterior wall is formed at the extreme inner margin by the parietals, and the remainder of the anterior wall

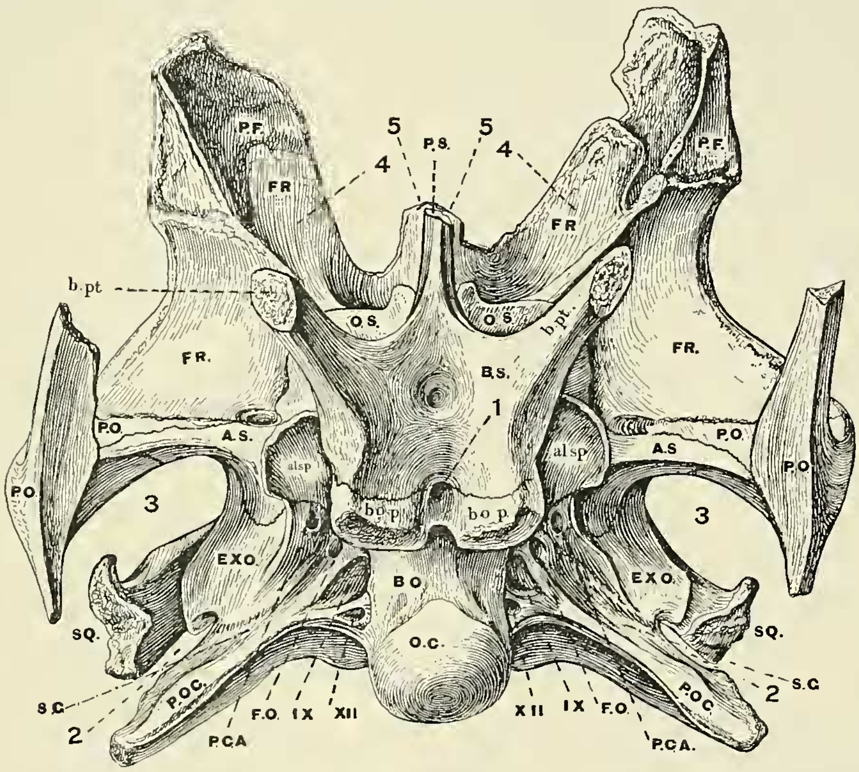

FIG. 10. Inferior view of posterior part of skull of Diplodocus (No. $\frac{662}{22}$, Car. Mus. Cat. Vert. Fossils, one half natural size). *O.C.*, occipital condyle; *BO.*, basioccipital; *P.OC.*, paroccipital processes of exoccipitals; *EXO.*, exoccipitals; *SQ.*, squamosals; *BS.*, basisphenoid; *AS.*, superior wing of alisphenoid; *alsp.*, inferior wing of alisphenoid; *P.O.*, postorbitals; *FR.*, frontals; *O S.*, orbitosphenoids; *P.S.*, presphenoid or rostral portion of basisphenoid; *P.F.*, prefrontal; *S.G.*, stapedial grooves; *P. C A.*, foramen for posterior carotid artery; *F.O.*, fenestra ovalis; *IX.*, glossopharyngeal foramen; *XII.*, hypoglossal foramen; *b.o.p.*, basioccipital processes; *b.pt.*, basipterygoid processes; 1, median eustachian foramen; 2, posttemporal fossæ; 3, supratemporal fossæ.

is formed by the posterior external surfaces of the postfrontals, the postorbitals, and the alisphenoid where the latter articulates between the postfrontal and the exoccipital. The internal surface of the upper end of the quadrate appears to form a small part of the inner margin of the supratemporal fossa above, but below enters into it to a larger extent.

The Infratemporal Fossæ (Fig. 3 and Plates XXIII. and XXVI.). — The infratemporal fossa is bounded above by the postorbital and the jugal, below by the quadrate and the quadratojugal.

The Orbital Cavities (Figs. 1, 3, 5, and 7–10 and Plates XXVIII. and XXVI.). — The orbital cavity is irregularly oval in form, with the longer axis lying in the direction of the longer axis of the skull. It is bounded above on its outer margin by the prefrontals, the frontals and the postfrontals; behind and below by the postorbitals, and below in front by the jugal. Its upper anterior margin is bounded by the supraorbital. The inner walls of the opening are formed by the nasals, the frontals, the orbitosphenoids and alisphenoids, and the process of the postorbital, which is thrust in between the frontal and the alisphenoid. The anterior portion of the wall is in part formed by the thin plate of the lachrymal, which articulates along the inner margin of the supratemporal.

The Narial Opening (Fig. 3). — The narial opening has been very accurately and correctly described and figured by Professor Marsh. It is, as he says, "very large, subcordate in outline, and is partially divided in front by the slender posterior processes of the premaxillaries. It is situated at the apex of the skull, between the orbits and very near the cavity for the olfactory lobes of the brain."

The Preorbital Vacuities (Fig. 3 and Plates XXIII., XXIV., and XXVI.). — The preorbital vacuity is phenomenally large, but by no means as large as it is represented in the restoration of the skull made by Mr. Hermann (A. M. N. H., No. 969) (see Plate XXVI.) and its outline is quite different, so far as can be determined from the specimens which are preserved in the United States National Museum. A comparison of the type skull, a photograph of which is given upon Plate XXIII. and of the accurate drawing published by Professor Marsh with the photograph of the skull restored by Mr. Hermann (a photograph of which is given upon Plate XXVI.) will show the great difference which exists. Unfortunately this portion of the skull employed by Mr. Hermann in making his restoration was missing, and the margins of this opening are wanting in the specimen, and in the restoration are wholly artificial.

The Mesial Foramen of the Maxillary (Fig. 3 and Plates XXIII., and XXIV.). — This opening, which does not occur, so far as is known, in any other genus of the Dinosauria, is about 5.5 cm. in length and about 3 cm. in width on its longest diameters. It is situated half way between the outer and inner margin of the maxillary bone and about midway between the posterior margin and the anterior extremity of the bone. It is very prominently and distinctly developed in both of the skulls, which are preserved in the collection of the United States National Museum. It has been, unfortunately, altogether ignored by Mr. Hermann in his restoration, and, as will be seen by reference to the photograph of this skull on Plate XXVI., it is not shown there. This foramen, which communicates with the interior of the nasal cavity, strongly suggests to the writer that it had a function supplementary to the function of the true narial opening.

The Foramina at the Junction of the Premaxillaries and the Posterior Processes of the Premaxillaries (Plate XXIV.). — At the point at which the premaxillaries touch the anterior extremities of the two long and narrow bones which Professor Marsh interprets as posterior prolongations of the premaxillaries (though these bones do not seem to the writer to be what Professor Marsh declares them to be) there is on either side of the anterior extremity of these bones a foramen approximately 3 centimeters in length and about .75 cm. in width. These two foramina extend with their longer axes parallel to the line of the symphysis of the two narrow bones, and the outer margin of each side is apparently formed by a narrow notch in the inner margin of the maxillary bone. These two foramina are very distinctly shown in Professor Marsh's type specimen (U. S. N. M., No. 2673). (See Plate XXIV.) They occupy a position which is relatively more nearly that which is held by the narial openings in many of the recent reptilia, and so far as the writer is able to judge from an examination of the skull, communicate with the narial cavity.

The Pineal or Parietal Foramen (Plate XXVIII.). — Professor Marsh, "Dinosaurs of North America," page 175, says: "On the median line, directly over the cerebral cavity of the brain, the type specimen of Diplodocus has also a fontanelle in the parietals. This, however, may be merely an individual peculiarity." On page 176 he says: "There is no true pineal foramen, but in the skull here figured, Plate XXV., there is the small unossified tract mentioned above. In one specimen of Morosaurus a similar opening has been observed, but in other Sauropoda the parietal bones even if thin are complete. The suture between the parietals and frontal bones is obliterated in the present skull, and the union is firm in all the specimens observed." A very careful study of the two specimens, which were jointly used by Professor Marsh while prosecuting his researches, as is evidenced by the drawings made at the time, some of which he used in his work upon the dinosaurs of North America, others of which he did not use, but which have been kindly placed at the disposal of the writer by the authorities of the United States National Museum, shows that in specimen No. 1921 (U. S. N. M. Catalogue, No. 2672) there is no evidence whatever of the existence of a pineal foramen. The opening in the top of the skull (see Plate XXIV.) is evidently due to artifical causes and has been produced either by accident, or by the use of an instrument. In the other specimen, No. 1922 (U. S. N. M. Catalogue, No. 2673), which is undoubtedly the specimen which Professor Marsh refers to as the "type," there is a protrusion upward of the matrix, with which the cerebral cavity had become filled, and the bone over this spot has largely disappeared, only a few flakes being adherent to the protruding mass of foreign matter. There is no depression at this point whatever, on the contrary there is an eminence. Both Mr. Hatcher and the writer were very skeptical as to the existence of a pineal or parietal foramen at this point, after we had carefully studied the original material upon which Professor Marsh based his description, and our skepticism was intensified by the study of the remarkably perfect posterior portion of the skull in our possession, to which reference has already been frequently made. In the latter specimen there is absolutely no evidence whatever of a pineal foramen. The two frontal bones unite by a suture which can be traced backward to the point where the frontals articulate with the parietals. (See Plate XXVIII., Fig. 1.) There are no Wormian bones and no evidence of the thinning out of the skull at this point. In the specimen which has been restored by Mr. Hermann of the American Museum of Natural History, he has represented a large and conspicuous foramen as existing at this point. Quite a considerable portion of the margin of this foramen is artificial. In another specimen belonging to the American Museum of Natural History, a photograph of which has been kindly sent to the writer by Professor Osborn, and which is reproduced on Plate XXVIII., Fig. 2, there is also shown an opening. A critical examination of this opening fails to disclose any true foraminal margins; on the contrary the edges examined microscopically show fractured surfaces. It is nevertheless quite possible that such an opening did exist in young and immature specimens and that it may have become closed up at a later period in the life of the individual.

The occurrence of such an opening, which is doubtful, but which, did it occur, must have disappeared with increasing maturity, does not seem to the writer to furnish any support to the theory of the existence, at all events in Diplodocus, of such an organ as the so-called "pineal eye."

Lesser Foramina of the Skull. — The beautifully preserved specimen (No. $\frac{662}{22}$, Carnegie Museum Catalogue of Vertebrate Fossils) shows with remarkable clearness the location of many of the smaller foramina of the posterior portion of the skull. These openings the writer has diligently compared with the foramina in the skulls of recent reptilia and with the foramina found in the skulls of extinct reptilia, so far as they are known and have been interpreted. He is under special obligations in this connection to Dr. C. W. Andrews of the British Museum for giving him an opportunity to compare the material in his possession with a portion of the skull of *Iguanodon bernissartensis* which is preserved in the British Museum and of which Dr. Andrews has published an interesting account.[4]

[4] *Annals & Mag. Nat. Hist.* (6th Ser.), Vol. XIX., p. 585.

Beginning at the point where the orbitosphenoids unite above we find a V-shaped fissure between the orbitosphenoids, which undoubtedly gave exit to the olfactory nerves. Just below this V-shaped opening the orbitosphenoids coössify for a short distance, and then by deep circular notches in their anterior margins (which notches are only separated by a short filament of bone on the median line) give exit to the second pair, or optic nerves. On the posterior margin of the orbitosphenoids, about their middle, where they coössify with the anterior surface of the alisphenoids, there are deep semicircular notches giving exit to the oculomotor and abducens nerves. Below the foramen just mentioned there are clustered three lesser foramina which evidently were intended to admit the anterior branches of the carotid artery and possibly also to give exit to veins. These foramina on the right side of the skull appear as three separate openings. On the left side of the skull the openings have become fused so as to form a somewhat large trilobate aperture.

Following the foramen which gives exit to the oculomotor nerves, at the point where the alisphenoids unite with the anterior surface of the exoccipitals and slightly below the level of the oculomotor foramen, there is a large foramen which is undoubtedly correctly determined as the trigeminal foramen. In outline, size, and location, it corresponds very closely to the trigeminal foramen in the skulls of recent reptilia.

In the lower margin of the exoccipital bone, somewhat above the line where it coössifies with the basioccipital, are four openings. The anterior opening which lies immediately behind the lower anterior wing of the exoccipital, which, as has been already said elsewhere, coössifies with the posterior wing of the alisphenoids, is a small foramen which very probably admitted on either side of the skull the posterior branches of the carotid artery. Immediately behind this is an opening which the writer interprets as the fenestra ovalis, leading away from which, along the lower margin of the paroccipital bone, is a groove which the writer interprets as the groove which held the stapes, which in the specimen in our possession is missing. Apparently no other location in the skull can be found save this for the exit of the auditory nerves, and a careful comparison of the skull with the skull of Sphenodon shows that this opening and the accompanying groove are closely analogous to the corresponding structures in the skull of the latter animal.[5] Succeeding this foramen is a foramen which the writer interprets as the exit for the glossopharyngeal nerves, and this foramen is in turn succeeded by a smaller fora-

[5] Sphenodon has no external ear, agreeing in this respect with many other recent reptilia and ophidia. It is possible that Diplodocus had no external ear.

men which passes through the lower margin of the exoccipital just at its point of union with the basioccipital and enters the posterior margin of the foramen magnum a little in advance of the occipital condyle. This foramen is most undoubtedly the foramen which gave exit to the hyoglossal nerve.

At the point where the basioccipital processes diverge anteriorly on the median line, just where union is effected between the basioccipital and basisphenoid bone, there is a deep foramen penetrating upward which the writer interprets to be, after the analogy of the crocodilian skull, the median eustachian foramen.

In addition to these foramina there are in the superior borders of the orbitosphenoid bones, where they unite with the frontals, small notches which may have given exit or entrance to blood vessels.

The attentive study of the foregoing account of the foramina of the cranium of Diplodocus reveals the fact that there is a close correspondence in the location of the various exits for the nerves of the brain between the skull under consideration and the skull of Iguanodon, a cast of the brain cavity of which was made by Professor Andrews and is beautifully delineated in the paper to which reference has been given. The brain of Diplodocus was however much more compressed antero-posteriorly. The cerebellum was less strongly developed, judging from a cast of the interior of the brain cavity of specimen No. 2673 (U. S. N. M.), which lies before the writer. The pituitary body in the brain of Diplodocus was not as strongly developed as in the brain of Iguanodon, though the impression of the interior cavity of the skull of Diplodocus before the writer is in many respects not as perfect as the impression secured by Professor Andrews, and it is therefore possible that the latter statement may hereafter require to be somewhat modified.

CERVICAL VERTEBRÆ.

The Atlas.

Unfortunately, in all the material, which has been collected by the different expeditions sent out by the Carnegie Museum, no specimen of an atlas, which could unmistakably and positively be referred to Diplodocus, was found. The American Museum of Natural History was so fortunate as to secure an atlas with the skull (No. 969). The elements are disarticulated and somewhat crushed, nevertheless not so much so as to render it impossible to easily and correctly adjust the parts. The atlas figured by Professor Marsh ("Dinosaurs of North America," Plate XXVII. Figs. 1 and 2), and reproduced by Mr. Hatcher in his account (Memoirs of the Carnegie Museum, Vol. I., p. 19, Figs. 4 and 5), if the atlas of Diplodocus, is undoubtedly that of an older specimen, in which the different elements have become thoroughly fused and coössified. The elements of the atlas represented in the specimen belonging to the American Museum of Natural History are an intercentrum, two neural arches, and the odontoid process, figures of which, through the kindness of Dr. H. F. Osborn, I am permitted to give.

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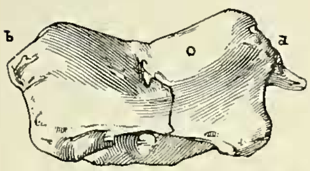

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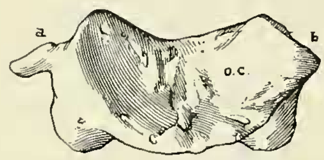

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FIG. 11. Posterior view of intercentrum of atlas. *a*, right neurapophysial facet; *b*, left neurapophysial facet; *o*, odontoid facet. (One half natural size.)

FIG. 12. Anterior view of intercentrum of atlas. *a*, right neuraphysial facet; *b*, left neuraphysial facet; *o.c.*, occipito-condylar facet. (One half natural size.)

FIG. 13. Inferior view of intercentrum of atlas. (One half natural size.)

The Intercentrum (Figs. 11–13). — The intercentrum is an irregularly oblong bone, flattened and somewhat concave on its lower side, sending forward a curving lip-like anterior projection along its lower anterior margin, and on either side of the hind margin throwing out two articular processes. The anterior surface is concave, adapted to accommodate the occipital condyle. The posterior surface is also concave, adapted to receive the odontoid process. On either side are broad facets for the right and left neural arches. The characteristic features of this bone are shown in the accompanying illustrations (Figs. 11, 12, and 13).

The Neural Arches (Figs. 14 and 15). — The neural arches are irregular bones, strongly concave inwardly and convex outwardly. They articulate with the inter-

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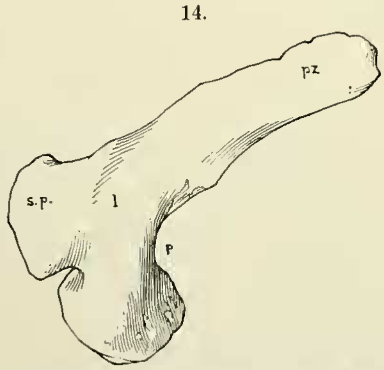

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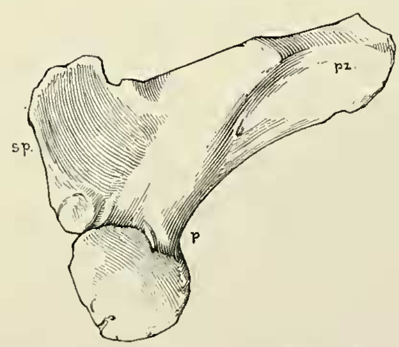

FIG. 14. External view of left neural arch of atlas. *p*, pedicle; *l*, lamina; *s.p.*, spinous process; *p.z.*, postzygapophysis. (One half natural size.)

FIG. 15. Internal view of the right neural arch of atlas. *p*, pedicle; *s.p.*, spinons process; *p.z.*, postzygapophysis. (One half natural size.)

centrum by means of a strongly-developed pedicle which flares out on all sides at the point where it coössifies with the intercentrum. In front the bone sends inwardly and upwardly a process which with the corresponding process of the opposite arch forms the covering of the upper half of the neural canal. These processes do not, either in the specimen before us, or in the specimen figured by Professor Marsh, seem to have united to form a neural spine, and they were probably bound together by ligamentary attachments. The comparatively short lamina sends backward a greatly elongated postzygapophysial process, which in its anterior portion is excavated on the lower surface, and at its extremity on the lower surface is adapted to articulation with the prezygapophyses of the axis. In the specimen figured by Professor Marsh this process is represented as broken off, and Professor Marsh's figure, in which an attempt is made to supply the missing portion by a dotted line, does not give a correct idea as to its actual length.

The Odontoid Process (Figs. 16–19). — The odontoid process was not found with the axis described and figured by Mr. Hatcher. He says (Memoirs of the Carnegie Museum, Vol. I., p. 20): "Only the base of the odontoid process is preserved, but this indicates that it was of moderate length with a slightly concave superior surface." A careful examination seems to show that what was preserved of this specimen was the petrified cartilage intervening between the axis and the odontoid, to which some fragments of the odontoid were adherent, a partial coössification between the odontoid and the axis having taken place. In the specimen preserved in the American Museum of Natural History, figures of which are herewith given, it is plainly seen that this bone which is morphologically the centrum of the atlas, existed as a separate element of the cervix, as is always the case in the Chelonians, and exceptionally in the mammalia, even including man. The bone which is herewith figured and described has apparently sustained some slight injury on its upper surface, more particularly on the left hand side. It appears to the writer that a piece of the upper surface has been flaked off. The bone shows a distinct fracture,

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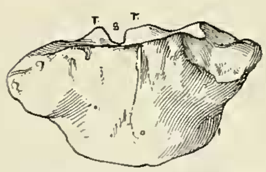

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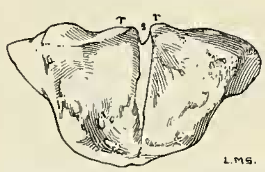

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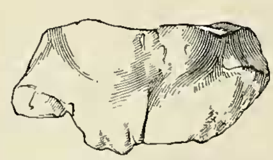


FIG. 16. Inferior view of Odontoid. *r.r.*, rugosities of upper posterior margin; *s.*, groove between rugosities. (One half natural size.)

FIG. 17. Superior view of Odontoid. *r.r.*, posterior rugosities; *s.*, groove through upper surface. (One half natural size.)

FIG. 18. Posterior view of Odontoid. (One half natural size.)

FIG. 19. Anterior view of Odontoid. (One half natural size.)

revealing the internal cellular structure on that side. Otherwise the bone shows well-preserved surfaces, and although slightly distorted by pressure, it is not so much distorted as to make it impossible to understand its relation to the atlas and axis. The bone may be described as having, roughly speaking, the form of a quarter of a sphere, the rounded surface fitting into the odontoid notch of the intercentrum of the atlas. This surface is not, however, perfectly rounded, but is somewhat constricted about the middle. The upper surface is approximately flat horizontally. Running through the middle is a small groove or sulcus, narrow in front and widening behind. The posterior surface is slightly concave, with two small rugosities projecting backwards, one on either side of the sulcus which has been described as running through the upper surface. The form of the bone is best understood by reference to the accompanying figures (Figs. 16–19). The superior surface of the odontoid of course formed, when in place, a portion of the lower wall of the spinal canal.

The Axis (Figs. 20–22). — The axis of specimen No. 84 (Carnegie Musum Catalogue of Vertebrate Fossils) has been very carefully described and has been well represented by Mr. Hatcher. He says in his description: "A short cervical rib without anterior process springs from the side of the centrum near its inferior margin and anterior extremity." A very careful reëxamination by the writer of the

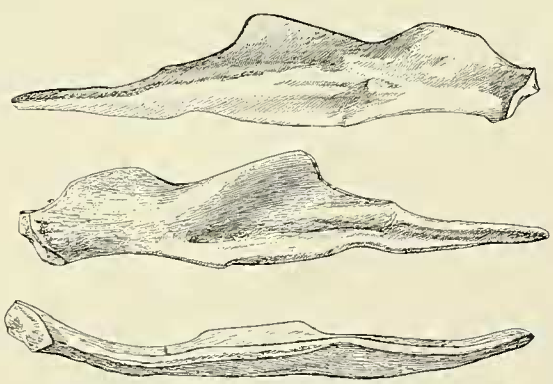


FIG. 20. Supposed rib of the atlas of Diplodocus preserved in the American Museum of Natural History. The upper figure is an external view of the rib, the middle figure is an internal view, the lower figure is an inferior view.

specimen upon which Mr. Hatcher's description was based leads him to think that the cervical rib on both sides has sustained injury, and that only a portion remains adherent to the centrum. Accompanying the elements of the atlas sent to the writer for study by the kindness of Professor Osborn are two bones, undoubtedly cervical ribs. They are both bones belonging on the right side of the centra. They are reported to have been found at the same place at which the atlas was found. The writer is inclined to think that the larger of these two bones (Fig. 20), was probably the rib of the atlas and indeed it requires but little effort to see that it might very well have served such a function, and that the smaller bone (Fig. 21) was the rib of the axis. Were the stump of the rib which remains attached to the axis in the Carnegie Museum, and which Mr. Hatcher has figured, removed, this smaller

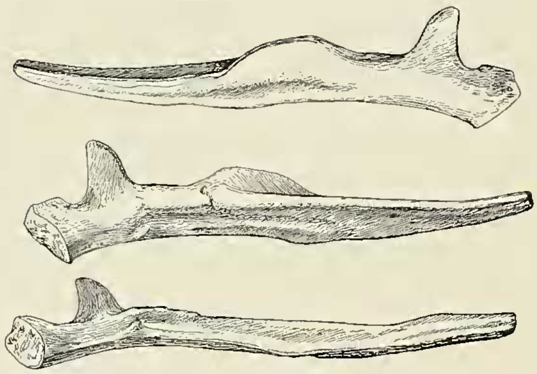


Fig. 21. Supposed rib of the axis of Diplodocus preserved in the American Museum of Natural History. The upper figure is an external view of the bone, the middle figure gives an internal view of the same bone, the lower figure is an inferior view.

rib might take its place and would undoubtedly articulate very neatly to the facet. In case the view entertained by the writer is correct, the form of the atlas and the axis with their attached ribs would be as given in the accompanying sketch (Fig. 22) rather than as given in the figure which has been published by Mr. Hatcher. Such a location of these parts has in its favor the analogy of the crocodilian skeleton.

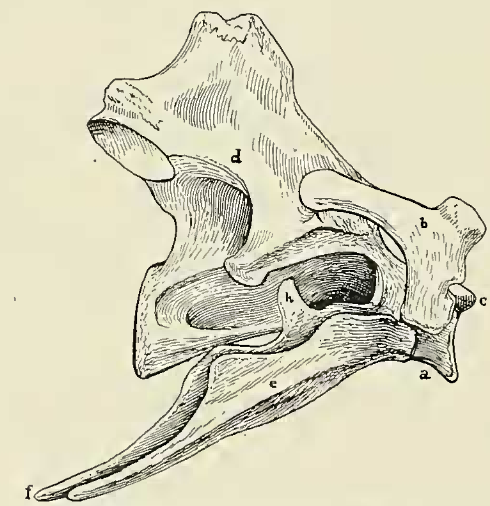


Fig. 22. Sketch of the manner in which the two cervical ribs preserved in the American Museum of Natural History may be supposed to have functioned in connection with the atlas and the axis. *a*, atlas; *b*, neural arch of atlas; *c*, odontoid process; *d*, axis; *e*, rib of atlas; *f*, rib of axis; *h*, anterior process of rib of axis.

The Cervical Vertebræ after the Axis. — Professor Marsh was undoubtedly in error in figuring as the cervical vertebra of Diplodocus the bone, an illustration of which is given in "Dinosaurs of North America," Plate XXVI., Fig. 3, and Plate XXVII.,

Fig. 3. This bone, the original of which was critically examined both by Mr. Hatcher and by the writer, is undoubtedly one of the cervical vertebræ of a Brontosaurus and not of a Diplodocus. The bones which were obtained by Professor Marsh in many cases came from what we are in the habit of calling "general quarries," that is, from deposits in which the bones of a number of individuals, sometimes representing different genera, are found commingled. The recovery by the Carnegie Museum in 1899 of the entire series of the cervical vertebræ of Diplodocus, most of them articulated and in the position held in the living animal has made the whole subject clear and any one at all familiar with the matter may easily verify for himself the correctness of the statement that Professor Marsh was in error in this particular instance. The fact that Professor Marsh had attributed one of the cervical vertebræ of Brontosaurus to Diplodocus had not been detected by Mr. Hatcher at the time that he prepared his first Memoir upon Diplodocus, but in Vol. II. of the Memoirs of the Carnegie Museum, p. 75, he points out the error into which Professor Marsh had fallen and calls attention to the fact that the comparison he made on p. 56 of his Memoir, between the cervical vertebræ of *Diplodocus carnegiei* and the cervical vertebræ attributed by Professor Marsh to *Diplodocus longus* is without value.

The cervical vertebræ belonging to the series after the axis have been so thoroughly and accurately described by Mr. Hatcher that it would be a work of supererogation for the writer to say anything in addition to what he has already so well said.

The Dorsal Vertebræ.

In a paper published by the writer in *Science*, N. S., Vol. XI., p. 816, it was stated that the number of dorsals ascertained to have belonged to specimen No. 84 (Carnegie Museum Catalogue of Vertebrate Fossils) was ten. At the time that this paper was written the vertebræ which are coössified and united with the ilia had not yet been freed from the matrix, and the fact that the anterior vertebra belonging to the five which are coössified in the sacral region might, as has been pointed out by Mr. Hatcher, be reckoned as a modified dorsal rather than as a true sacral, had been overlooked. Mr. Hatcher makes the first of the bones coössified in the sacral region the eleventh dorsal. He has, however, very aptly pointed out (Memoirs of the Carnegie Museum, Vol. I., p. 30) that it is a matter of individual opinion as to whether this bone should be reckoned as a sacral or as a dorsal. This vertebra marks the transition from the dorsals to the sacrals, and, as has been pointed out by Mr. Hatcher, "functions as a sacral." The number of vertebræ in Diplodocus to be reckoned as belonging to the dorsal series depends altogether upon the view which is taken of the composition of the sacrum. If the vertebræ which coössify in the sacral region and support the ilia are regarded as the sacral bones, then there are but ten dorsals. If the anterior vertebra of the five in the sacral region is considered, as has been done by Mr. Hatcher and Professor Osborn, a modified dorsal, then there are eleven.

The Sacral Vertebræ.

Professor Marsh ("Dinosaurs of North America," p. 182) says, "There are four vertebræ in the sacrum. On Plate XXVIII. he gives a figure of the lower side of the sacrum in which he shows but three vertebræ. Professor Osborn in his monograph states, as Professor Marsh stated in his text, that there are four sacral vertebræ, and reckons as these four the three figured by Marsh in his plate and the succeeding vertebra." Mr. Hatcher says:

"The sacrum in Diplodocus may be regarded as composed either of three, four, or five vertebræ, according to the individual conception as to which should be considered as sacral vertebræ. If the sacrals are made to include all those vertebræ, which, though formerly belonging to the posterior dorsals or anterior caudals, have laterally become so modified as to function as sacrals by affording support to the ilia, either by bearing true sacral ribs, or by the means of greatly expanded transverse processes, or by both of these methods, then the sacrum of Diplodocus must be considered as composed of five vertebræ."

The fact is that five of the vertebræ are firmly coössified by their centra in this region and unite in supporting the ilia. All five perform the functions of sacral vertebræ. It appears to the writer that probably the most correct view to take of the the matter would be to say that the three vertebræ intervening between the modified dorsal and the modified caudal vertebra are the true sacrals, and to reckon the anterior vertebra with the dorsal series and the posterior vertebra with the caudal series.

The Caudal Vertebræ.

Mr. Hatcher accepted Professor Osborn's interpretation of the sacrals, fixing their number at four and including in the sacral series the modified caudal to which reference has been made by the writer in the preceding paragraph. Mr. Hatcher and Professor Osborn begin the caudal series with the vertebra next succeeding the one which functions as a sacral. Professor Osborn estimated the number of caudals as thirty-seven. Mr. Hatcher in his Memoir stated that "This number will more than likely be increased through the addition of a number of rod-like posterior caudals now known to obtain in the tails of certain other Dinosaurs." The correctness of the prediction made by Mr. Hatcher was strikingly shown by the discoveries made in 1901 and 1903. Mr. W. H. Utterback succeeded in 1903 upon the Red

Fork of Powder River, in finding the tail of a Diplodocus with the caudal vertebræ articulated and succeeding each other in regular order from very near the extremity of the tail forward to a point considerably beyond its middle. The study of this series of caudals in connection with the three other specimens acquired by the Carnegie Museum reveals the fact that the number of vertebræ estimated by Professor Osborn falls far short of the true number. In making the restoration which has been placed in the British Museum we utilized the twelve anterior caudals belonging to specimen No. 84 (Carnegie Museum Catalogue of Vertebrate Fossils) which had been found articulated and in the position held in life. From the caudal vertebræ found in connection with specimen No. 94 (Carnegie Museum Catalogue of Vertebrate Fossils) we selected nineteen caudals corresponding to the caudals belonging to the very beautiful specimen in the American Museum of Natural History which are figured by Professor Osborn and which when placed in position showed normal relationships to the anterior caudals, the position of which was absolutely ascertained, as well as to each other. The caudal No. 32 was supplied from the material obtained by Mr. Utterback on the Red Fork of the Powder River, belonging to specimen No. 307 (Carnegie Museum Catalogue of Vertebrate Fossils). Caudals 33 to 36 inclusive were taken from specimen No. 94. Caudals 37 to 73 inclusive represent the series found articulated and in position by Mr. Utterback in 1903. (See Plate XXIX.)

We were induced to select the vertebræ used in the caudal series taken from specimen No. 94 (Carnegie Museum Catalogue of Vertebrate Fossils) because of the fact that the specimen from which they were taken, though slightly smaller than specimen No. 84, corresponded more nearly in size to that specimen than caudals belonging to the specimens which were subsequently found. Caudals from 37 to 73 inclusive represent a specimen, which, judging from other bones (not vertebræ), which were found in connection with its caudal series, was a decidedly smaller individual than specimen No. 84, and even smaller than specimen No. 94. The total length of the caudal series made up in the manner which has been described, although at the first glance calculated to fill the observer with astonishment, is very probably shorter than the entire series would have been, had the specimen No. 307 attained as large a size as the other specimens which were utilized. Furthermore, in spite of the enormous prolongation of the tail which is shown, it is positively ascertained that not all of the vertebræ belonging to the caudal series are represented in it. The last caudal in the series plainly shows an articulation at its posterior extremity for the attachment of another caudal, and there may have been several succeeding it.

To recapitulate, we have brought together and arranged in making our restoration seventy-three caudals, not reckoning in this number the first modified caudal, which forms part of the sacrum. The vertebræ from 1 to 12 inclusive pertained to specimen No. 84; from 13 to 31 inclusive and from 33 to 36 inclusive, to No. 94. Caudal 32 and caudals 37 to 73 inclusive belonged to specimen No. 307.

The long whip-like prolongation of the tail of Diplodocus, the exact function of which is not known and can only be surmised, recalls the enormous prolongation of the tail which is shown in some recent reptilia. The writer has examined the skeletons of a number of species of recent reptiles and finds that the number of caudal vertebræ in *Iguana tuberculata* is sixty, in *Brachylophus fasciatus* sixty-five, in *Polychrus marmoratus* seventy, and in *Varanus niloticus* from ninety-seven to one hundred.

A comparison of the bones obtained in connection with the specimen of *Cetiosaurus leedsi* Hulke, preserved in the British Museum, indicates that they corre-

Fig. 23. Outline drawing of a series of posterior caudal vertebræ of *Cetiosaurus leedsi* Hulke. (One sixth nat. size.)

spond approximately to the caudal vertebræ 47 to 56, inclusive, in the skeleton of Diplodocus. The bones of Cetiosaurus are relatively shorter and stouter than the corresponding bones in Diplodocus, but these bones both in the case of Cetiosaurus and of Diplodocus are remarkable because of the fact that they articulate both in front and behind by convex, or almost conical surfaces, showing that the posterior extremity of the tail possessed the very largest degree of flexibility. I am indebted to the courtesy of Dr. Arthur Smith Woodward for permission to give illustrations herewith of these vertebræ in *Cetiosaurus leedsi* Hulke. Fig. 23 shows an outline drawing made by Miss Alice Woodward, and Fig. 24 is a reproduction of a photo-

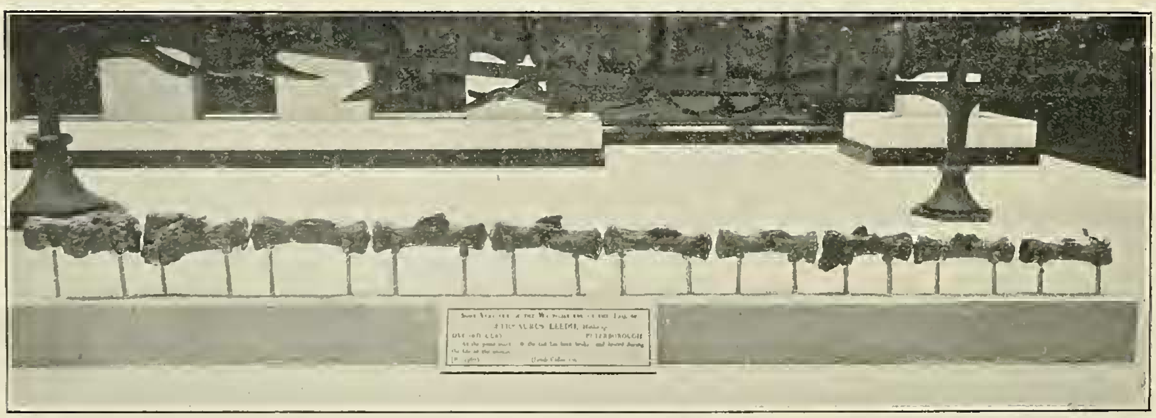


Fig. 24. Vertebræ of posterior part of the tail of *Cetiosaurus leedsi* Hulke, as exhibited in the British Museum (Natural History).

graph of the specimens as they are arranged for exhibition in the Gallery of Paleontology at South Kensington. Similar series of very slender rod-like caudal vertebræ have been recently found in connection with specimens of Brontosaurus.

That the enormously elongated, and at its extremity highly attenuated tail of these great reptiles was liable to injury, is shown by the caudal vertebræ of Diplodocus in the collections of the Carnegie Museum, as well as by the caudal vertebræ of *Cetiosaurus leedsi* preserved in the British Museum. In specimen No. 84 (Carnegie Museum Catalogue of Vertebrate Fossils) caudals 2 and 3 are coössified, as has been already pointed out by Mr. Hatcher in his Memoir, and this coössification appears to be pathological rather than normal. In specimen No. 94 caudals Nos. 20 and 21 are firmly coössified, as are also caudals Nos. 24 and 25. The coössified caudals Nos. 20 and 21 were described and figured as doubtfully Nos. 17 and 18 by Mr. Hatcher on page 36 of his Memoir. Maturer and more careful study has proved that they should be given the position which they now hold in the restored skeleton. The coössification in the case of both of these instances is evidently due to traumatic causes. An examination of the photograph of the rod-like caudals of *Cetiosaurus leedsi* (Fig. 24) shows plainly that several of these bones have sustained injury, as might easily happen by being crushed under the feet of other individuals, or when used possibly for purposes of defense in giving blows to the right and to the left.

Plate XXIX. represents the caudals from No. 37 to No. 73 inclusive as these were found in serial order by Mr. Utterback.

The Chevrons.

In the restoration of the skeleton represented by Mr. Hatcher in the Memoirs of the Carnegie Museum, Volume I., Plate XIII., the anterior chevrons are somewhat exaggerated in length. The chevrons had not been put into place at the time of Mr. Hatcher's death, and it fell to the writer to supervise this part of the work. The original drawing for Mr. Hatcher's plate was made by Mr. R. Weber, who based his drawings of the chevrons upon material which had not been experimentally assigned to positions in the skeleton. Mr. Hatcher's death compelled the writer to take up the work. The anterior chevrons used in making the reproduction were those found with our specimen No. 84, and these are shorter than those represented in the drawings made for Mr. Hatcher by Mr. Weber and accord, therefore, more nearly in proportion with physical requirements. Many of the chevrons after the first six are reproductions of those found and described by Professor Osborn in his paper on Diplodocus published in Volume I. of the American Museum of

Natural History, and we are greatly indebted to him for having kindly allowed us the use of this material. It is interesting to know that the chevrons of Cetiosaurus vary in form in much the same manner as those of Diplodocus, as has been shown by Professor A. Smith Woodward in his paper recently published in the Proceedings of the Zoölogical Society of London, 1905, Volume I., p. 239.

The Sternal Plates.

Among the puzzling elements of the skeleton of Diplodocus, as well as of other dinosaurs which have been discovered, are two bones to which Professor Marsh has given the name of "sternal plates." The location of these elements of the skeleton has occasioned a great deal of perplexity, and a careful examination of Professor Marsh's writings upon the subject shows very plainly that this distinguished authority was by no means certain as to either the location or the function which these large sesamoids hold in the skeleton. In his "Dinosaurs of North America," Plate XXII., Fig. 1, he represents the sternal plates of Brontosaurus with their thickened extremities directed upward and forward, and with their flattened and broadly expanded extremities directed downward and backward. On p. 179, Fig. 30, he represents the corresponding bones of Morosaurus in a reversed position. Both Mr. Hatcher and the writer discussed at great length and repeatedly the question as to the proper location of these elements, and finally reached the conclusion that the enlarged and thickened extremities of the bones, which manifestly display provision for the attachment of large masses of cartilaginous matter, should be located so as to point backward, while the thin margins should be directed upward and forward, thus making provision for the attachment for the ligamentary skeleton of the sternum, no portions of which have been found in a petrified form in any specimen which we have discovered, although in one specimen of Brontosaurus, which is described by Professor Marsh, there were found what he terms sternal ribs, which, manifestly, were more or less cartilaginous in their structure. It appeared to the writer, after a careful consideration of the subject, as altogether most probable, that the position which has been assigned these elements in the restoration is the correct one. There is no instance of record in all of the paleontological researches which have thus far been made, of the discovery of these bones in the exact position which they held in the life of the animal. They usually occur commingled with the anterior portions of the skeleton whenever this is found approximately *in situ*. In specimen No. 84 the sternal plates of the Diplodocus lay about the middle of the abdominal region, in a position to which they might easily have been brought as the bones of the decaying skeleton were shifted about by the agency of carnivorous animals or by the action of currents of water. That considerable shifting of this sort took place is shown by referring to the diagram of Quarry "C" (Memoirs Carnegie Museum, Vol. I., Plate I.) where it will be seen that the ischia had been shifted forward and were found lying in a position anterior even to that of the sternal plates.

The Supposed Clavicle. — In connection with specimen No. 84 (Carnegie Museum Catalogue of Vertebrate Fossils), there was found a bone, which was described by Mr. Hatcher on p. 41 of his Memoir upon Diplodocus. He expressed himself as strongly inclined to the opinion that it was a clavicle. In the Memoirs of the Carnegie Museum, Volume II., p. 74, he described a second specimen of a similar bone found in connection with skeleton No. 662 and gave figures. Mr. Hatcher adhered to the opinion that this bone might very well have functioned as a clavicle, though he also suggests that the bone may be regarded as an os penis. At the time that the restoration of the skeleton of Diplodocus was being set up I had with me a reproduction of the second specimen which belongs to skeleton No. 662, and Mr. Barlow, the skilful preparator in the Paleontological Laboratory of the British Museum,

FIG. 25. Photograph of the two sternal plates and the supposed clavicles as provisionally and temporarily placed by the author in the pectoral region of the restored skeleton at the British Museum, May, 1905. The so-called clavicles have since been taken down and laid aside.

very kindly made for me a model, reversing the curvature so as to adapt this model for use upon the left side of the skeleton. The reproductions, one on the right side, the other on the left, were then placed in position by me, functioning as clavicles, the bifid extremity being located at the point of the symphysis of the coracoid with the scapula, at which point there is some evidence in all the specimens which we have found of provision for ligamentary or possibly osseous attachments. The broad, somewhat expanded distal extremities of the bones, as fitted into the skeleton, were found to adapt themselves very well to the back of the sternal plates, and the shallow groove running obliquely across the anterior surface of the bones seemed to adapt itself almost perfectly to the upper margin of the sternal plates as placed. Of all the supposable positions in which this bone might be put so as to function as a

Fig. 26. Lateral view of the sternal plates and supposed clavicles as provisionally placed by the author in the pectoral region of the restored skeleton at the British Museum. The so-called clavicles were taken down and laid aside by the author.

clavicle, this appeared to the writer to be the most plausible, and the models of the bones were allowed to remain in this position for a short time. While in this position two photographs were taken, one from directly in front of the skeleton and the other at the side. These two photographs are herewith reproduced (Figs. 25 and 26), and serve to explain what the writer has said in the preceding sentences.

Against the location of the bones in the position tentatively assigned to them in the reproduction is *in the first place* the fact that the distal extremity of the supposed clavicle is brought into position behind the sternal plates. Such a location is very unusual, though not absolutely without an apparent parallel in other genera of the reptilia. In the Plesiosauria, as has been pointed out by Professor H. G. Seeley[5] and also by Dr. C. W. Andrews,[6] the clavicles are placed on the dorsal side of the scapular girdle. Figs. 27 and 28 represent the position of the clavicles in a specimen of *Cryptoclidus oxoniensis*, which is preserved in the British Museum. Fig.

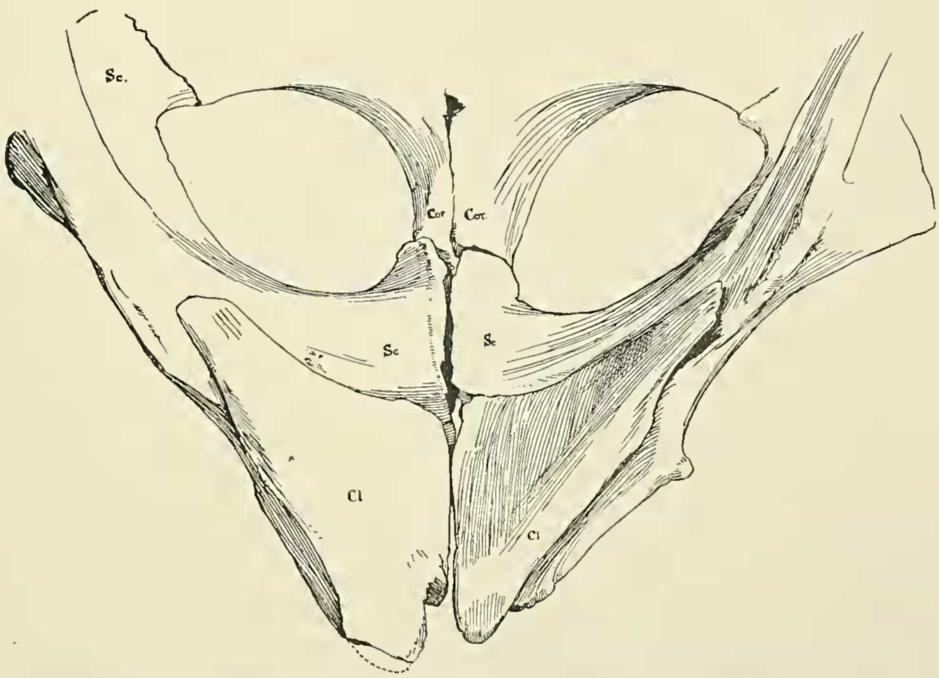


FIG. 27. Superior view of the pectoral girdle of *Cryptoclidus oxoniensis*. *Cl.*, clavicle; *Cor.*, coracoid; *Sc.*, scapula. (Drawn by Miss Alice B. Woodward.)

27 furnishes a view from above of the clavicles lying in position upon the shallow-grooved surfaces in the scapula where they were found *in situ* when the specimen was discovered. I understand from Dr. A. Smith Woodward that there is no doubt

[5] "The Nature of the Shoulder Girdle and Clavicular Arch in Sauropterygia," by H. G. Seeley, F.R.S. *Proceedings of the Royal Society*, Vol. LI., pp. 119–151.

[6] "The Pectoral and Pelvic Girdles of Muraenosaurus plicatus," by C. W. Andrews. *Ann. and Mag. Nat. Hist.*, April, 1895, pp. 429–434.

that the bones in this specimen of *Cryptoclidus* are located in the position which they held when first found. Fig. 28 is a view of the scapular girdle of the same specimen viewed from directly in front and showing the clavicles lying on the dorsal surface of the scapula. To place the supposed clavicles of Diplodocus in the position shown above in Figs. 25 and 26 has therefore the analogy of the location of the clavicles in the skeleton of *Cryptoclidus* to support it.

In the second place, against the employment of these bones as clavicles is the fact that, so treated, their articulation with the margin of the scapula and the coracoid where the latter bones unite must be made by a bifid extremity. The writer, from an anatomical standpoint, does not contemplate such an articulation as this with satisfaction. It is without analogy in other forms to support it. He knows of no case among recent or extinct reptiles where the articulation of the clavicles with the scapular elements takes place by means of bifid extremities.

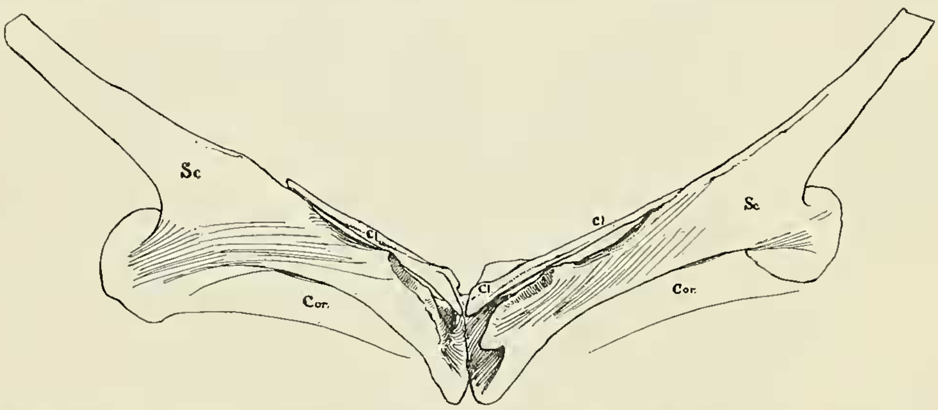


FIG. 28. Anterior view of the pectoral girdle of Cryptoclidus. *Cl.*, clavicle; *Cor.*, coracoid; *Sc.*, scapula. (Drawn by Miss Alice B. Woodward.)

Baron F. Nopsca, Jr., who occasionally called upon the writer while at work upon the restoration, has since caused a paper to be presented at a meeting of the Zoölogical Society of London which has been published (cf. *P. Z. S.*, London, 1905, Vol. II., Part I., p. 269). In this paper the Baron undertakes to break a lance in defence of the suggestion made by Mr. Hatcher, that this bone might possibly have had the function of an os penis. Against this view there is very much to be said. As Mr. Hatcher pointed out in Volume II. of the Memoirs of the Carnegie Museum, p. 74, "The marked asymmetry of the bone" offers a potent argument against the probability of this assumption. At the time that I was experimenting at South Kensington, in the endeavor to utilize these bones as clavicles, I had with me only a reproduction of the specimen which had been found in connection with skeleton No. 662, but since my return to the Carnegie Museum I have very carefully reexamined not only the specimen from No. 662, but also the specimen which was found with No. 84. I find that the two bones are, in spite of what Mr. Hatcher said, highly dissimilar, and it even appears that they may have functioned as bones of opposite sides of the skeleton. Their shafts are not cylindrical, but flattened on one side and convex on the other. They are not alike at either extremity. When placed side by side with the lines of their curves approximately parallel, it is at once seen that the broad flattened extremity of the bone recovered with skeleton No. 662 lies in a plane varying from that in which the corresponding portion of the bone found with skeleton No. 84 by an angle of at least 40°. (See Fig. 29.) If these

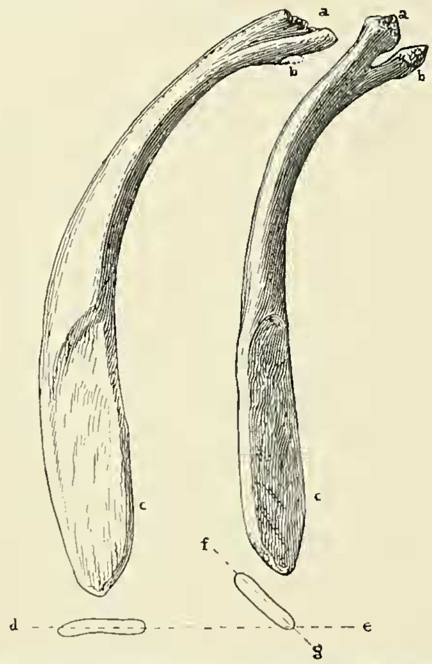


Fig. 29. The two supposed clavicles lying side by side with their curves approximately parallel. The figure on the left is that of the bone recovered with skeleton No. 662, that on the right is the bone recovered with skeleton No. 84. *a-b*, bifid extremities of bones; *c*, broad flattened ends of bones; *d-e*, direction assumed by flattened end of bone from No. 662; *f-g*, direction assumed by flattened end of bone from No. 84.

bones are regarded as belonging to the male copulatory organ then it becomes plain that the position held by this organ in the two specimens must have been wholly different. Accepting for sake of argument the view that the flattened end of the bone represents the portion of the os penis which was located in ligamentary attachments, proceeding from the corpus fibrosum, with its plane placed vertically after the analogy of *Lutra* and other animals, then its distal extremity lay in nearly the same plane pointing downward, with the convex side of the shaft on the right, and the flattened side of the shaft on the left. Assigning to the specimen from No. 84 the same position, so far as its flattened, supposedly proximal end is concerned, its distal extremity must have pointed upward and strongly to the right. If, however, leaving the direction of the flattened ends of the bones out of sight, we place the two with the flattened sides of their shafts in one position, so that the shafts occupy the same relative position, then the bone from No. 662 points downward, while the bone from No. 84 points upward and strongly to the left. It is wholly inconceivable to the writer that such absolutely dissimilar arrangements should exist in the case of the penis bone of any animal. Sectional drawings of the shafts of these bones also show that they are very different from each other. (See Fig. 30.) The bone

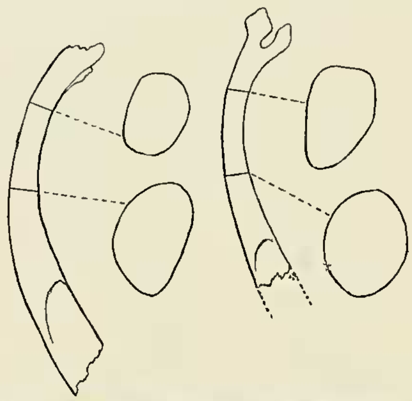


FIG. 30. Sections one third of natural size of shafts of supposed clavicles. The upper figures represent sections taken four and one half inches from the bifid end of the bone, the lower figures represent sections taken nine and one half inches from the same point. The outlines of the bones themselves are reduced much more than one third and are wholly diagrammatic. That on the left is from skeleton No. 662, that on the right from skeleton No. 84.

taken from skeleton No. 662 is very rib-like, the shaft having a flattened surface on one side and a convex surface on the other. The bone taken from skeleton No. 84 has the same flattening on one side and a convexity on the other, though not so strongly developed. The bifid extremity of the bone from No. 662 shows that a small portion of one of the branches has been broken off, but irrespective of this fracture the end does not agree with the bone from skeleton No. 84 either in the shape or direction of the surfaces of the bifurcating extremities. While Mr. Hatcher was inclined to the view that both bones represented specimens taken from the same side of the animal, it appears to the writer that they may very well be bones from opposite sides. Not only are these bones, therefore, asymmetrical, but they differ in a marked manner from each other to such an extent as to suggest that they did not occupy the same place in the skeleton, but were most probably from opposite sides.

Finally, against the theory advanced with great hesitation and rejected by Mr. Hatcher, but which Baron Nopsca has undertaken to defend, that these bones might have functioned as ossa penis, is not only the fact of their asymmetry and the marked differences which exist in the two specimens, which are so great as to make it appear, that, wherever located in the skeleton, they must have held opposite, or, at least, very different positions, but the fact, that, so far as is known to the writer, there is no record in any museum, or in all of the literature of the subject, of the existence of an os penis among any of the reptilia, living or extinct, whereas clavicles are found in many reptilian genera. The similarity of these bones to the os penis of *Lutra*, which is pointed out by Baron Nopsca, is curious, but entirely fails to carry conviction with it to my mind, and more particularly since I have carefully reëxamined the original specimens which are in my custody. The fact of the bifidity of the penis of *Struthio*, which is pointed out by Baron Nopsca, does not appear to the writer to possess great weight. The tracing of resemblances between the struthious birds and the dinosauria appears to the writer, as he knows it does to others, to be in danger of being greatly overdone. Bifidity in the penis is characteristic of the organ in many widely different groups of animals.

There is another thought or suggestion which has presented itself to the mind of the writer during his studies, namely, that these bones may possibly have been sternal ribs connected in some way by strong cartilaginous or ligamentary attachments with the roughened and thick ends of the sternal plates, or imbedded in cartilaginous or fibrous muscular tissues which do not exist in a fossil state in our specimens. In this connection reference may be made to the sternal ribs obtained with a skeleton of Brontosaurus, which Professor Marsh has figured in his work upon the Dinosaurs.[7] It is worthy of note that the length of the longest and most attenuated of these bones is almost identically that of the supposed clavicle described by Hatcher. It is furthermore inconceivable to the writer that there should have been no sternal ribs in Diplodocus. There must have existed a system of central supports for the lower part of the wall of the huge thoracic cavity.

The attempt to assign these bones to a position in which they may function as clavicles is not wholly satisfactory to the writer. To regard them as ossa penis is to the writer a far more thoroughly unsatisfactory hypothesis, as it was to his colleague, Mr. Hatcher, who first suggested it. The conclusions of my friend Baron Nopsca, reached in a labored argument based upon seven propositions, the first five of which bear only indirectly upon the subject, and the last two of which are positively incorrect, are in the judgment of the writer untenable. The true position of these bones is still in doubt, and having left the reproduction of them for a few days in the position to which I had tentatively and experimentally assigned them

[7] "Dinosaurs of North America," p. 171.

in the model of the skeleton, I removed them and turned them over to Dr. Arthur Smith Woodward, requesting him to keep them until with the progress of discovery we come to a point where we may be better able to tell what was the rôle which they actually played in the osseous system of Diplodocus.

In concluding this brief paper upon the osteology of Diplodocus the writer cannot forbear making passing reference to the interest which was manifested by the public in the restoration, which was formally presented to the Trustees of the British Museum by Mr. Carnegie, on May 12, 1905. He is informed that the number of persons resorting to the Museum in South Kensington, after the announcement had been made that the restoration was on view, exceeded the attendance at the institution at any time since the building was first thrown open to the public. It happened that at the time of the presentation Parliament was in session, and it was exceedingly interesting, as well as amusing, to observe the manner in which the fancy of the knights of the quill and brush seized the work of the paleontologist to aid them in the field of political caricature. A score of amusing cartoons bearing upon the political events of the day, in which the Diplodocus was made to do service, appeared in the daily papers of England. In the field of commercial advertisement the great reptile has been used, and the writer has discovered a number of advertisements in which rude representations of the creature have been given, in order to attract the attention of the public to wares which are described below the cuts. Not only has the Diplodocus been pressed into service by the caricaturist and the advertising agent, but the modeler has employed its form for decorative purposes. "Diplodocus vases," bearing on their sides figures of the beast in high relief, have been placed upon the market in London by one of the best known firms engaged in the manufacture of majolica.

Thus the huge reptile, which a score of years ago was unknown, has become more or less familiar, although there remain a number of doubtful points as to its osteology to be solved by future study and research.

EXPLANATION OF PLATE XXIII.

The upper figure represents the left side of the skull which bears Professor Marsh's number 1922 (U. S. N. M., No. 2673). The mandible on the right side is dislocated and crushed down.

The lower figure represents the right side of the skull which bears Professor Marsh's number 1921 (U. S. N. M., No. 2672). The specimen is badly broken and crushed in part, but the occipital region is in part better preserved than is the case in the specimen represented in the upper figure. The drawings of the skull of Diplodocus published by Professor Marsh, as well as other drawings, which he caused to be made, but which he did not publish for reasons which are plain to the critical student, show that he utilized both of these skulls in preparing his descriptions and published figures.

SIDE VIEW OF SKULLS OF *DIPLODOCUS LONGUS* MARSH, PRESERVED IN THE UNITED STATES NATIONAL MUSEUM.

EXPLANATION OF PLATE XXIV.

The figure on the left is a view from above of the skull of Diplodocus bearing Professor Marsh's No. 1922 (U. S. N. M., No. 2673). The photograph shows that the right side of the skull has been more exposed to crushing than the left.

The figure on the right is a view from above of the skull of Diplodocus bearing Professor Marsh's No. 1921 (U. S. N. M., No. 2672). Only the right half of the anterior portion of the skull is preserved in this specimen. But it shows the posterior parts of the skull in some respects to better advantage than they are shown in the skull catalogued by the U. S. N. M. as No. 2673.

TOP VIEW OF SKULLS OF *DIPLODOCUS LONGUS* MARSH, PRESERVED IN THE UNITED STATES NATIONAL MUSEUM.

EXPLANATION OF PLATE XXV.

The figure on the left is a view of the back of the skull of Diplodocus bearing Professor Marsh's No. 1922 (U. S. N. M., No. 2673). The basioccipital and the paroccipital processes of the exoccipitals are broken and for the most part missing, only the articulating surface of the latter remaining *in situ* on the left side.

The figure on the right is a view of the back of the skull bearing Professor Marsh's No. 1921 (U. S. N. M., No. 2672). The occipital condyle, the outline of the foramen magnum and the mode of the articulation of the bones forming the back of the skull is revealed more clearly in this specimen than in No. 2673, but there is much distortion and crushing.

BACK VIEW OF SKULLS OF *DIPLODOCUS LONGUS* MARSH, PRESERVED IN THE UNITED STATES NATIONAL MUSEUM.

EXPLANATION OF PLATE XXVI.

The upper figure gives a view of the left side of the skull (A. M. N. H., No. 969). A very large proportion of the superficies is artificial, and the margins of the antorbital vacuity are wholly artificial and do not conform to the outline of the type described by Professor Marsh (U. S. N. M., No. 2673). The quadrate bone at the proximal end has been broken, and appears in the restoration to show as two separate bones. The articulation of the quadrate with the quadratojugal does not agree with that shown in Marsh's type (U. S. N. M., No. 2673), and is artificial. The anterior portions of the maxillaries and premaxillaries, being largely artificial, fail to show the characteristic foramina of this region of the skull.

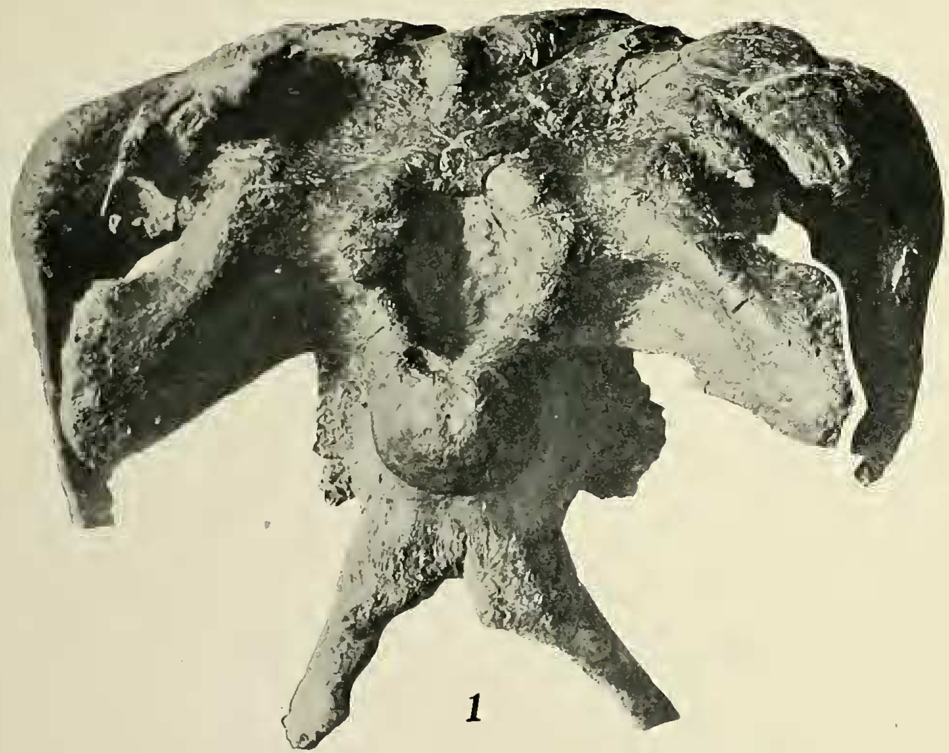
The lower figure gives a hind view of the same skull (A. M. N. H., No. 969).

PHOTOGRAPHS OF SKULL OF DIPLODOCUS PRESERVED IN THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK (CAT. NO. 969).

EXPLANATION OF PLATE XXVII.

FIG. 1. Posterior View of the Back Part of the Skull of Specimen No. $\frac{662}{22}$, Carnegie Museum Catalogue of Vertebrate Fossils.

FIG. 2. Anterior View of the Back Part of the Skull of Specimen No. $\frac{662}{22}$, Carnegie Museum Catalogue of Vertebrate Fossils.



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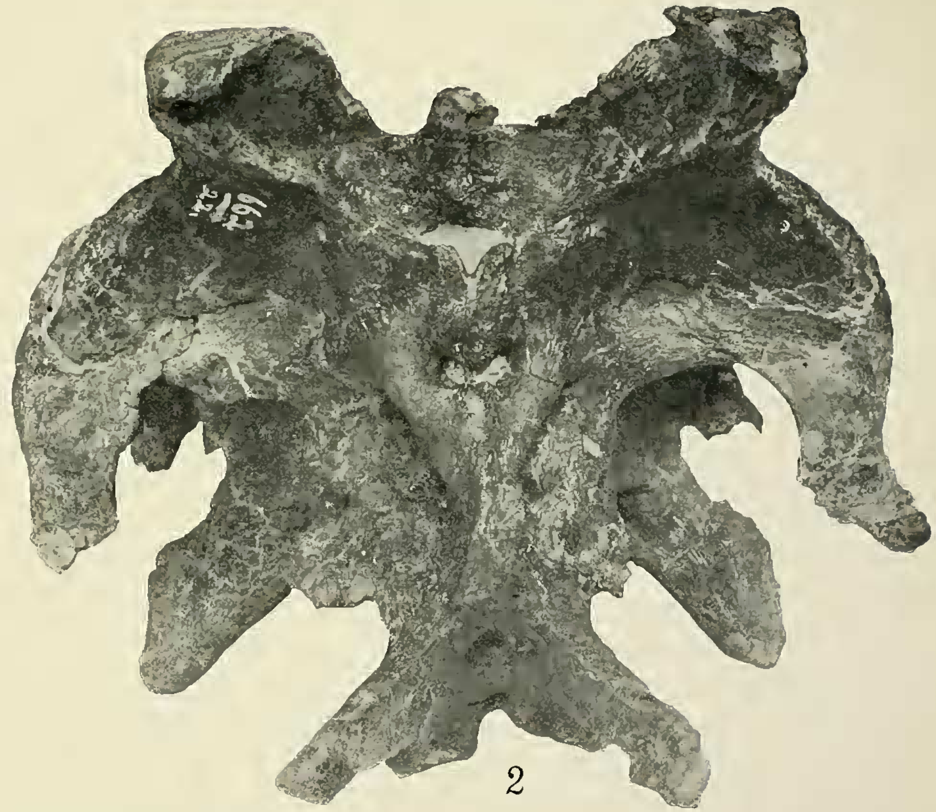

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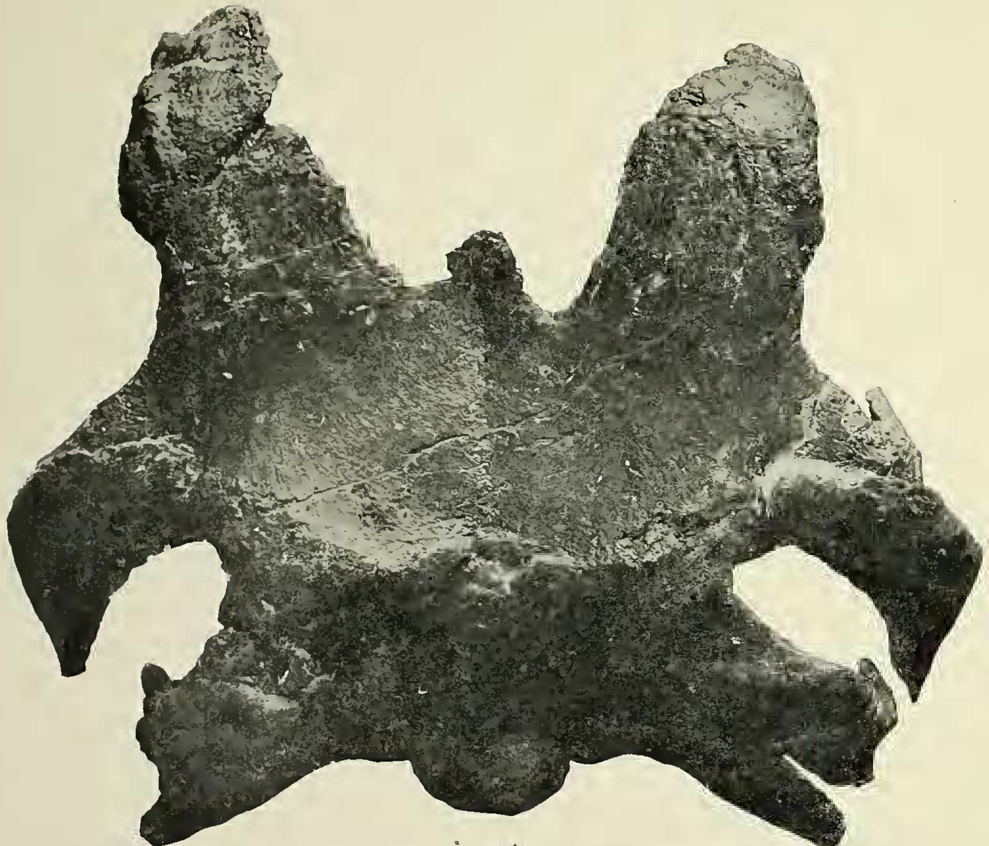
Posterior and Anterior View of Back Part of Skull of Diplodocus. (Specimen No. $\frac{662}{22}$, Carnegie Museum Catalogue of Vertebrate Fossils.)

EXPLANATION OF PLATE XXVIII.

Fig. 1. Superior View of the Back Part of the Skull of Specimen No. $\frac{662}{22}$, Carnegie Museum Catalogue of Vertebrate Fossils.

Fig. 2. Superior View of the Back Part of the Skull of Specimen No. 694, American Museum of Natural History Catalogue of Vertebrate Fossils.



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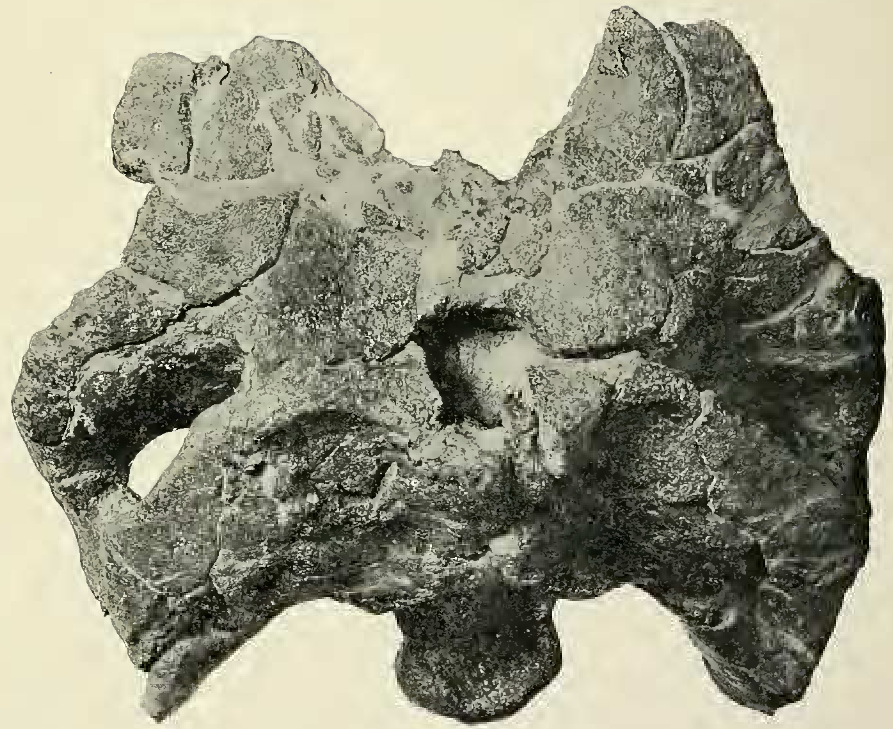
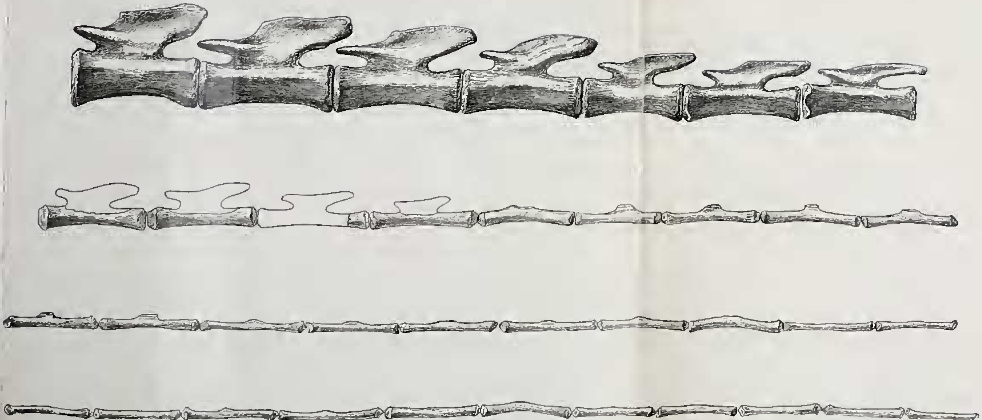


2

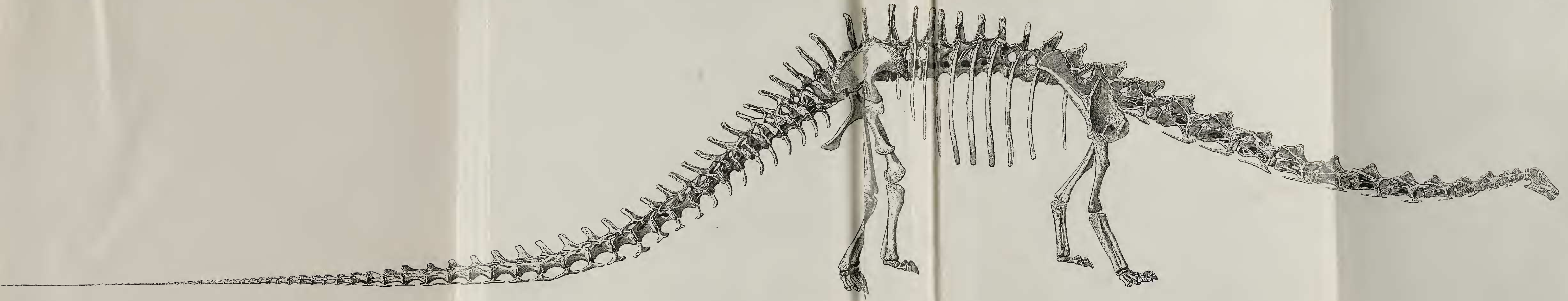
SUPERIOR VIEW OF BACK PART OF SKULLS OF DIPLODOCUS.

EXPLANATION OF PLATE XXIX.

The Plate gives an outline of the caudal vertebræ (Nos. 37–73 inclusive) of the tail of a Diplodocus discovered by Mr. W. H. Utterback on the Red Fort of Powder River lying in serial order. The figures on the Plate are reduced to one fourth the natural size.



POSTERIOR CAUDAL VERTEBRÆ OF *DIPLODOCUS CARNEGIEI* HATCHER, NOS. 37–73 INCLUSIVE, FOUND ARTICULATED ON RED FORK OF POWDER RIVER, WYOMING, BY W. H. UTTERBACK.



Restoration of the Skeleton of *Diplodocus Carnegiei* Hatcher. (The drawing is based upon that given by Hatcher in the Memoirs of the Carnegie Museum, Vol. II., Plate VI., with modifications based upon thresearches of J. B. Hatcher and W. J. Holland, made subsequently to the publication of that figure, which it now supersedes.)